



# جامعة الأمير محمد بن فهد PRINCE MOHAMMAD BIN FAHD UNIVERSITY

**College of Engineering**

**Department of Electrical Engineering**

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**Senior Design Project Report**

## **The Curiosity Rover**

**In partial fulfillment of the requirements for the  
Degree of Bachelor of Science in Electrical Engineering**

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## Abstract

In our project we focus on improving the rover and create the ultimate exploring device for scantiest in order to enrich and expand our knowledge. As a result, we try to create something that can help the rover to perform it expected function. None the less, we designed our rover to have a number of four ultrasonic sensors in the front and another one in the back and each one of them attached to a servo motor, all this for detecting huge obstacles and look for another path to avoid it. Our smart automated rover will be able to benefit from this advanced feature by programming a specific code to enable all this. On the other hand, for the manual control mode, we set an extra challenge for our team to include a long-distance video streaming feature as we felt the high importance of this feature for our purposes. Our smart rover that can be manually controlled or fully automated require us to include more components in order to be the ultimate exploring rover. Consequently, we have the sun tracking solar panels subsystem which will help the rover to charge during the sunshine and track it directly to increase the efficiency. In order to perform that, we designed a lightweight base for the solar panels. In addition, this will able our rover also in the autonomous mode and charge the battery, so it will go by itself and charge itself. Additionally, our smart rover will be able to pick samples by our 3D printed programmed robotic arm that will add more value in exploring purposes. Moreover, we are trying to make the rover goes to rough surfaces. Nevertheless, by designing our lightweight aluminum chassis with its specific shapes, our dream will become a reality.

Our Rover will perform feature such:

- It can go to places that humans do not get hurt
- It can be used to take samples by using a robotic arm
- It can go to rough surfaces
- The rover can be controlled or it can be in automated mode

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## **1. Introduction**

Robotics occupies a special place in the arena of interactive technologies. It combines sophisticated computation with rich sensory input in a physical embodiment that can exhibit tangible and expressive behavior in the physical world. What is an appropriate first role for intelligent human-robot interaction in the daily human environment? The time is ripe to address this question. Robotic technologies are now sufficiently mature to enable interactive, competent robot artifacts to be created. The study of human-robot interaction, while fruitful in recent years, shows great variation both in the duration of interaction and the roles played by human and robot participants. In cases where the human caregiver provides short-term, nurturing interaction to a robot, research has demonstrated the development of effective social relationships. Nevertheless, the rover's size and shape are born from practical constraints regarding the home environment together with the goal of emulating the aesthetics of the exploratory rovers. Users should be able to easily manipulate the rover physically. Also, the rover must be small enough to navigate cramped spaces and large enough to traverse outdoor, grassy terrain and curbs. There are some problems being addressed by an engineers. For example, they build a rover which has solar panels but they don't think about dust and it will affect the rover for loss the connection. Also, the main problem can be the size of the rover and how heavy it is. Moreover, the robotic arms are not strong enough to catch heavy samples that will help scientists in their research. There could be some solution to improve and help the rover.

### **1.1 Project Definition**

The Curiosity Rover is a robotic vehicle remotely controlled or fully autonomous backed up with sun tracking solar panels for on-board self-battery charging. The rover will be designed to move across rough terrain that may otherwise cause risks and danger for individuals. The smart rover will be able gather data on environmental parameters and collect samples of a wanted object using a robotic arm.

## 1.2 Project Objectives

1. Learn about robotic vehicles used in space exploration.
2. Design a smart and automated rover.
3. Build and program the rover.
4. Implement sun tracking solar panels for on-board self-battery charging.

## 1.3 Project Specifications

List:

1. Chassis that can go over rough terrain.
2. Remotely controlled robotic arm.
3. Can be used in remote control mode, or it can go in autonomous mode.
4. Solar panels with sun tracking feature to maximize battery charging.
5. Multiple 12 V motors (one in each wheel) to provide more power.
6. Sensors to detect obstacles and avoid them in autonomous mode.

## 1.4 Product Architecture and Components

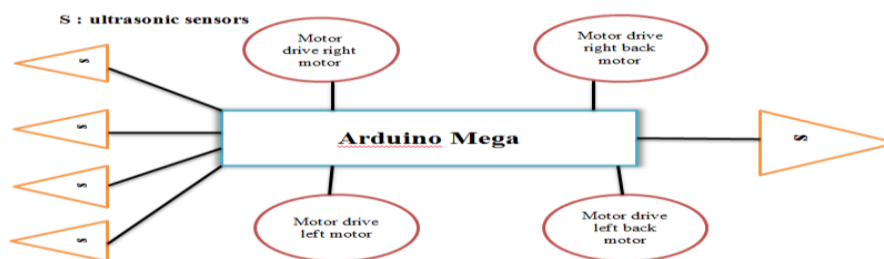


Figure 1

In Figure 1, the architecture diagram shows how we used 5 ultrasonic sensors for avoiding obstacles covering all areas of possible hits. Also, we used 4 motors drive for our six wheels because the motor has a high current so we try to avoid damaging our motors. Also, the motor drive can go up to 20 A.

## 1.5 Applications

The rover can be used as:

- It can take samples and help scientists in their research.
- It is very helpful for exploring and discovering purposes.
- It can navigate over rough surfaces and terrain.

- It does the required tasks while consuming green energy from the sun tracking solar panels.

## 2. Literature Review

### 2.1 Project background

#### Mars Spirit Rover

On February 13, 2019, NASA tweeted out a sad message: “To the robot who turned 90 days into 15 years of exploration: You were, and are, the Opportunity of a lifetime. Rest well, rover. Your mission is complete.” See Figure 2.



Figure 2.

It is strange to be sad a little saying these words. To feel sad about a robot on another planet. Thus, let us look back at the history of the Mars Exploration Rovers Spirit and Opportunity to go through their creation, launched to Mars, the amazing discoveries they made, and of course, how they finally died.

In the 1970s, NASA’s Viking Landers demonstrated that it was possible to land gently on the surface of Mars, to sample the rocks and atmosphere. The problem with a lander was that it was stuck to its landing site. The lander needed to be able to travel around with a rover to perform geologic research on Mars. This technology had been tested on the Moon, by the Soviet Lunokhod 1 rover, with operation of 11 months. The Soviets attempted to send rovers to Mars, but their Mars 2 and 3 missions failed.

It was until July 4, 1997, when NASA landed the Mars Pathfinder mission on the surface of Mars, with its tiny Sojourner rover. This mission lasted for just two months, with the rover exploring just a few rocks around the landing site. From this mission, though, NASA learned several lessons about what it would take to travel across the surface of Mars, performing geology on the go for months and months.

These lessons became the Mars Exploration A and B rovers, later named Spirit and Opportunity. These twin rovers were designed to be much larger than Sojourner, virtually the most enormous mass that could be sent to Mars using a smart airbag landing system that had been developed for Pathfinder.

Their primary science goal was to find evidence that liquid water had ever existed on the surface of Mars. The Red Planet is cold and dry today, but if Mars was once warmer and wetter, it could have once had life.

Spirit was launched on June 10, 2003, and Opportunity was followed on July 7, 2003. Spirit arrived on November 20, and Opportunity on December 11 of the same year. Both rovers arrived during the northern winter/southern summer on Mars using a method pioneered by Mars Pathfinder. For their landing sites, NASA scientists chose locations they hoped would give the best shots of finding evidence of past water. Both rovers were initially given a 90-day mission timeline. Nevertheless, months into their missions, it was clear that these hardworking robots would earn many extensions.

The rovers were equipped with a range of instruments that would let them analyze their surroundings, such as their Rock Abrasion Tools, or RATs. These were grinders they could use to scour the top layer of rock. Then they would use their microscopes to take close up pictures of the rocks for geologists on Earth to study, as well as spectrometers to study the chemicals that made up the rocks. Rove, grind, analyze, and repeat!

Electrostatically charged Martian dust clung to the rovers' solar panels, degrading their efficiency, and this was how NASA expected the rovers would eventually fail. Without enough electricity, they would not be able to keep their electronics warm during the frigid nights on Mars. By 2005, Spirit's panels had decreased their power output to 60%, and operators figured it was just a matter of time. On March 9, the rover's panels suddenly jumped up to 93% efficiency gain, and Spirit recorded images of dust devils speed across the surface of Mars. These cleaning events, whether they are dust devils or some other kind of phenomenon, kept the rovers alive, allowing them to work for years longer than initially planned. However, the rovers were already starting to get wear and tear on the surface of Mars. A significant problem came when one of Spirit's front wheels had seized up. In order to compensate, NASA had the rover drive backward, dragging its dead wheel behind it. In 2007, a global dust storm whipped up across the entire planet of Mars. Astronomers have seen these dust storms in the past, and they can significantly darken the skies from the surface of Mars. NASA announced that the 2007 storm was blocking about 99% of the direct sunlight falling on the rovers' solar panels. If their electronics got cold enough, the rovers would fail. Both were carrying tiny pellets of decaying plutonium, which kept them warm, as well as electric heaters. However, if the

batteries ran out before the sunlight returned, they would not be able to recover. However, fortunately, the storm is gone, and the rover kept moving.

In 2010, Spirit was exploring a region called Troy. It had lost another wheel in the back, so it was severely crippled when it was stuck in soft soil. Try as hard as they could; the operators could not get the rover out of the sand trap. This was key because the rovers typically spent their winters parked on a south-facing slope where they could get the maximum amount of sunlight they get on their solar panels. As the Martian summer shifted to Martian winter, Spirit received less and less sunlight. Its last communication back to Earth was on March 22, 2010. After that, it probably continued to shut down its systems one at a time, until it did not have enough power to keep its electronics warm during the freezing winter. Throughout its exploration, Spirit had driven almost 8 kilometers and spent 2,208 days actively exploring the surface of Mars.

As Spirit succumbed to the frigid Mars winter, Opportunity continued its explorations once it escaped the tiny Eagle crater. The end began in May 2018 when NASA Mars Reconnaissance Orbiter began tracking the buildup of another global dust storm. By June 12, it covered a quarter of the surface of Mars, a week later; it was encircling the entire planet. This was not an ordinary dust storm, though, it was the most powerful that had ever been recorded, shrouding the atmosphere so that very little sunlight could fall on Opportunity's panels. The rover hunkered down, shut off every system, and tried to make its power last long enough for its heaters to keep it alive during the event. By July 23, the dust storm started to subside, but there was no communication from Opportunity. Mission operators continued to send commands to the rover through 2018 and into 2019. However, after more than 600 failed attempts to reach Opportunity, NASA finally declared the mission official was over. On Wednesday, February 13, 2019 scientists from NASA's Jet Propulsion Laboratory announced that they had done all they could, Opportunity was gone too. In the end, Opportunity had driven over 45 kilometers across the surface of Mars, lasting 5,250 days - almost 15 years. So much longer than the 90 days that was initially planned. Between the two of them, the rovers sent back 342,000 raw images of the surface of Mars. It is going to be sad for a while, reporting on the exploration of Mars, knowing that only Curiosity is still on the move.

However, we will not have to wait long. The Mars 2020 rover is under construction right now, and next year we will see it blast off for Mars, bringing another set of eyes to the Red Planet. Europe's ExoMars rover will follow it in 2021, recently renamed to the Rosalind Franklin rover after one of the discoverers of DNA. Look forward to a day, in the far future, when explorers find Spirit and Opportunity again, repair and send them out to continue exploring the surface of Mars again.

### **Venus Program**

We are always talking about Mars when we mention rovers. There is a fleet of spacecraft probing, orbiting and moving around Mars. The Red Planet is the focus of attention because it is reasonably close and offers humanity a viable place for a second home with the

right techniques and technology; we may be able to make a sustainable home there. We mapped the surface of Mars in detail, and we know what it looks like from the surface.

However, Venus is another planet we need to keep in mind. It is bigger and closer than Mars. A hellish death scape would kill a human in moments if he/she ever set foot on it, but it is still pretty exciting and mysterious to visit.

It is a surprise to know that many spacecraft went to Venus and land there and send back to us accurate data with photos to Venus surface. It was a unique achievement of Soviet scientists, and some developed technologies in progress might help us get back, and explore it longer. Let us have a look at the Soviet Venera program. The first time humanity saw the surface of Venus from Venus itself.

In the 60s of the 20th century, the height of the cold war is racing, the Americans with the Soviets were accelerated research to be the first explorer to the Solar System. The first satellite to orbit Earth was achieved by Soviets, the first human to orbit Earth was by Soviets again, the first flyby and landing on the Moon were Soviets. Also, the first flyby of Mars was Americans success, the first flyby of Venus was recorded by Americans, and so on.

The Soviets aimed at sending a lander down on the surface of Venus, but, Venus planet has its particular challenges. Every place on the whole planet shows the same 462°C or 864°F. Moreover, the atmospheric pressure on the surface of Venus is 90 times comparing to Earth. Being down at the surface is the same as being beneath a kilometer of Earth ocean. Venus rains sulphuric acid, figuring this out took the Soviets a few tries. Landing on Mars is hard. If the aim is direct to the surface, the spacecraft will burn up due to atmosphere thickness, but the atmosphere is not thick enough to use parachutes to a soft landing on the surface. Landing safely on the surface of Venus, on the other hand, is extremely easy. The atmosphere is so thick that parachutes can be used if they can aim at a target and launch a parachute capable of handling the terrible environment; the soft landing is pretty much assured.

Their first try to flyby Venus was Venera 1, on February 4, 1961. Nevertheless, it failed even to escape Earth's orbit. Venera 2, which launched on November 12, 1965, followed this but it went off course just after launch. Venera 3 destroyed on November 16, 1965, and was aimed to land on the surface of Venus. The Soviets lost communication with Venera 3, but it is believed it did crash land on Venus. Venera 4 was next, sent on June 12, 1967. The Soviet scientists had little information about what the surface of Venus was. They did not know precisely the atmospheric pressure of Venus, so Soviet guessing it may be a little higher pressure than Earth, or it was hundreds of times Earth pressure. It was tested with high temperatures and scary deceleration. They thought they had built this thing plenty tough. Venera 4 reached at Venus on October 18, 1967, and attempted to survive a landing. Temperatures on its heat shield were recorded at 11,000°C, and it experienced 300 Gs of deceleration. The initial temperature was a pleasant 33°C, but then as it descended towards the surface, temperatures increased to 262°C. Then, they lost communication with the probe, killed by the horrible temperature.

The Soviets have continued improving their techniques and learning from past lessons. Venera 5, 6, 7, Etc. Until Venera 14 were launched and got back with essential data about Venus. The longest time Venera spacecraft last on Venus was Venera 13, which lasted for 127 minutes before losing the communication with Earth. Other advantages of the Venera program that we were able to take photos from the Venus surface and detect lightning strikes on Venus. Finally, we were able to measure the temperature and the pressure on Venus accurately.

It is one thing for a lander to reach the surface of Venus, stay for a few minutes, and then lost from the horrible environment. What we want is some rover, like Curiosity, which would survive on the surface of Venus for weeks, months, or years and do more science. However, computers do not like this kind of heat. Engineers at NASA's Glenn Research Center have improved a new type of electrical circuitry that may be able to operate with those kinds of temperatures. The new circuits were examined in the Glenn Extreme Environments Rig, which can simulate the surface of Venus. It can mimic the temperature, pressure, and the chemistry of Venus's atmosphere. The circuitry, initially designed for hot jet engines, lasted for 521 hours, functioning correctly. If all goes well, future Venus rovers might be fabricated to survive on the surface of Venus without needing the complex and short-lived cooling systems. This discovery might start a completely new era of exploration of Venus.

### **University Rover Challenge**

The Mars Society competition (The University Rover Challenge) (URC) is for students at universities to design and build a robotic rover helping the first explorer to Mars to perform their tasks there. The competition is conducted yearly at the Mars Desert Research Station, outside Hanksville, Utah in the United States. Competition place was chosen due to its similar geological features of Mars sandy surface. In addition to being a barren desert area, the chemical composition of area soil has a similar to soil on Mars. The competition has also extended globally to contain the European Rover Challenge, Canadian International Rover Challenge, and the Indian Rover Challenge as a portion of the rover competition Sequence.

The goal of the University Rover Challenge is to inspire students to create and improve skills in robotics, develop state of the art in rovers, and work in multi-disciplinary groups with collaboration between scientists and engineers. The challenge was started in 2006 with competitions held yearly each summer since 2007.

Specific situation details change each year as groups master given tasks and to encourage flexibility in designs and improve the abilities of the rovers each year. Rovers are compulsory to perform teleoperated or autonomous jobs that would contribute to astronauts in the field. Teleoperated tasks are achieved from control stations with no visual view of the rover, only what can be determined through video and data links from the rover or sensors positioned by the rover. It is assumed the workers are also on Mars, so there is no delay in the communications signal. For 2019, tasks include some features going to be discussed in the following paragraphs.

The first task was **System Acceptance Review (SAR)**, teams requisite to hand over a written report and a short video describing and representing the design and capabilities of the rover to complete the required tasks, technical plan, and group management.

**Science Mission**, the objective is to conduct in-situ analysis with the rover, involving life discovery testing of samples. Teams must examine multiple sites of biological interest, using devices and methods of their choice, where they must conduct a study of samples entirely onboard the rover. The task aims to decide the presence or absence of life, either extinct or extant, at designated sites. After the 20-30 minutes of examination time, teams must also make a short presentation to provide to the judges on-site, which shows their results, analysis, and conclusions. The analysis is expected to be related to the setting on Earth while representing an understanding of how these observations would convert to a Martian setting.

**Extreme Retrieval and Delivery Mission**, rovers will be obligated to pick up and transport objects in the field and deliver aid to spacemen. Rovers have to pick up and deliver objects in the field, such as rocks, toolboxes, hammers, screwdrivers, and such things. Rovers are required to cross a wide variety of terrain anything from soft sandy zones, to rock and boulder fields, to steep drops. Teams are given approximate GPS coordinates for individually pickup and delivery place and hypothetically specific instructions for particular objects. Scoring is based on groups' ability to pick up and deliver objects to their right locations.

**Equipment Servicing Mission**, Rovers shall be required to execute several handy operations on a mock-up equipment system. Likely tasks outlined in 2019 rules include:

- Tighten captive screw to secure drawer.
- Operate a joystick, push buttons, flip switches, turn knobs.
- Turn a hand crank.
- Replace an electronics board using a rugged board-to-board connector.

In 2017, it was required for rover to draw a carriage carrying a fuel canister to a generator, fill up the fuel tank, switch the regulator on gas cylinders, and start the generator by clicking on a button. Previous equipment jobs have included pumping air into a blowup habitat and cleaning solar panels.

**Autonomous Travel Mission**, rovers will be required to autonomously navigate between indications in this staged mission across reasonably tricky terrain. Here, autonomous means without teleoperation that is, without operators from the base location giving directions or user input. The rover must make all its choice-making on board. However, teleoperated exploring is allowed in earlier stages. The markers in this duty are tennis balls and estimated GPS coordinates specified to teams as get more complicated phases. The GPS coordinates will become increasingly unclear, and there will be more between the tennis balls, demanding obstacle avoidance and autonomous wayfinding. Besides, teleoperated inspection is allowed in the earlier phases, but not in the later ones.

The idea behind the URC's formation is that the kinds of rovers groups are building would assist spacemen in the field, controlled remotely by another spaceman. This imagined use case drives the competition is highlighting on teleoperation and ability to complete tasks that a human might need to. It is the same as equipment repairing, retrieval, and delivery. In its first year, only four groups participated: Penn State University, Brigham Young University, University of Nevada Reno, and University of California Los Angeles. There were only two responsibilities, a Science Task, and a task to install a mock radio repeater in the field. URC representative Kevin Sloan says they were uncertain what to expect, but were "blown away by the quality". The University of Nevada Reno gained that year, winning a \$5000 cash prize, which was reduced to \$1000 in following years.

## 2.2 Previous Work

In our search on related academic research to our project topic, the following four research found. The first research title is "DESIGN AND CONSTRUCTION OF A ROBOTIC VEHICLE TO ASSIST DURING PLANETARY SURFACE OPERATIONS" Done by Christopher Anthony Follette. A dissertation submitted to the Graduate Faculty of University of North Dakota in partial fulfillment of the requirements for the degree of Master of Science in 2013. The second research title is "Systematic Structural Optimization of a Next Generation Lunar Rover Chassis" by Ryan Alexander Pitre. A thesis submitted to the Graduate Program in Mechanical & Materials Engineering in conformity with the requirements for the Degree of Master of Science for Queen's University in Kingston, Ontario, Canada on September 2015. The third research title is "Development of a Mars Exploration Rover for RASC-AL Exploration RoboOps Competition with an Extended Kalman Filter Based Navigation System" by Benjamin J Knabenshue. A thesis submitted to the Graduate Faculty of West Virginia University in partial fulfillment of the Requirements for the Degree of Master of Science in Electrical Engineering in 2013. Finally, a research with the title of "ESA ExoMars Rover PanCam System Geometric Modeling and Evaluation" By Ding Li. It is presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of Ohio State University in 2015.

The first research is, "DESIGN AND CONSTRUCTION OF A ROBOTIC VEHICLE TO ASSIST DURING PLANETARY SURFACE OPERATIONS." About the close future, astronauts will discover new planetary grounds in the Solar System. To enable highest performance, these astronauts will need to use all of the tools at their dumping. It is suggested that one of these tool is a planetary surface rover designed specifically to support the astronauts throughout their Extra-Vehicular-Activities (EVA's). This rover is designed and constructed to function in concert with existing analog planetary surface structure at the University of North Dakota (UND). An astronaut located on the planetary surface, enabling real-time operation and obstacle avoidance, will remotely control this rover. The rover performance primarily as a relay for audio and video connection between the astronauts in the ground and the Inflatable

Lunar Habitat (ILH), or another planetary outpost. This rover will be designed to allow storing tools and samples, freeing the astronauts from the boring and physically difficult task of carrying items for extended distances encumbered by an EVA outfit.

The second research “Systematic Structural Optimization of a Next Generation Lunar Rover Chassis” utilized topology and size optimization to improve a lunar rover chassis in purpose to reduce basic mass while satisfying the necessary surface and launch vehicle loading criterion. Improved interest in lunar exploration has provided a prospect for Canada to participate in a Lunar Priesting Mission in association with NASA. Queen’s University, in association with Neptec Design Group, has established methodology to produce the structural design of the following generation lunar rover chassis using systematic design optimization methods to reduce the physical mass of the chassis. Usual lightweight design can be reached using lightweight materials, advanced industrialized processes or systems, and design optimization. Due to the exceptional requirements for a spaceship, the proposed research is partial to specific materials and processes; therefore, weight decrease is achieved completely through design optimization.

The third research is “Development of a Mars Exploration Rover for RASC-AL Exploration RoboOps Competition with an Extended Kalman Filter Based Navigation System.” The primary aim of this research is to improve a navigation system for practice on a rover designed for the NASA-NIA Revolutionary Aerospace Systems Concepts Academic Linkage (RASC-AL) Survey RoboOps experiment. This opposition takes place at NASA’s Johnson Space Center Rock Yard, a test facility with numerous obstacles including sharp hills, craters, rocks and unattached sandy terrain. In addition to the challenges of the terrain, the rover’s operators must control it from West Virginia University’s campus. It was experiential during the 2012 competition that a main challenge was an absence of situational consciousness; the operators had to navigate the big test area with only late video from two little resolution cameras. This research pursues to provide better understanding of the rover’s location in the rock area through the development of an accurate navigation aid system.

The fourth research “ESA ExoMars Rover PanCam System Geometric Modeling and Evaluation” is about The ESA ExoMars rover, intentional to be sent to the Martian surface in 2018, carrying a drill and a suite of instruments committed to geochemistry and exobiology research. To achieve its scientific part, high-precision rover localization and topographic mapping will be central for traverse path planning, safe planetary surface procedures and accurate implanting of scientific annotations into a global spatial context. For purposes like this, the ExoMars rover PanCam system will acquire an imagery network providing visualization information for photogrammetric algorithms to concentrate the rover and generate 3-D mapping produces.

In our project “Curiosity Rover”, we will carry what these researches reach of conclusion and try to apply it as much as possible in our project. We are going to gather these valuable information, build on it to improve our design and get the best thing we can to introduce the final demo of the Curiosity Rover.

## **3. System Design**

### **3.1 Design Constraints**

#### **3.1.1 Design Constraints: Environmental**

One of the design constraints that we have faced is environmental. It is important to take care about environmental constraint. What we are facing here is energy consumption, dust and climate change. For the energy consumption we had to be careful about it, so we had to consider the amount of energy that is used by process. In addition, for dust and climate change, we have to have special wheels that can be used in all weather conditions.

#### **3.1.2 Design Constraints: Economic**

We have faced another constraint regarding the overall budget, which is the economic constraint. We had to think more than once to have the estimated budget as low as possible, and we have to finish the project within the estimated budget. To estimate the most appropriate budget for our project, we have taken into consideration all the components and materials, such as, the chassis, Arduino Mega, wires, wheels, the battery, the DC Motors...etc.

### **3.2 Design Methodology**

We have divided the project into several parts to make it easy to handle and test. The main part of the project is to build a rover and insure it functions properly.

Phase 1 (Term 1, Design M.):

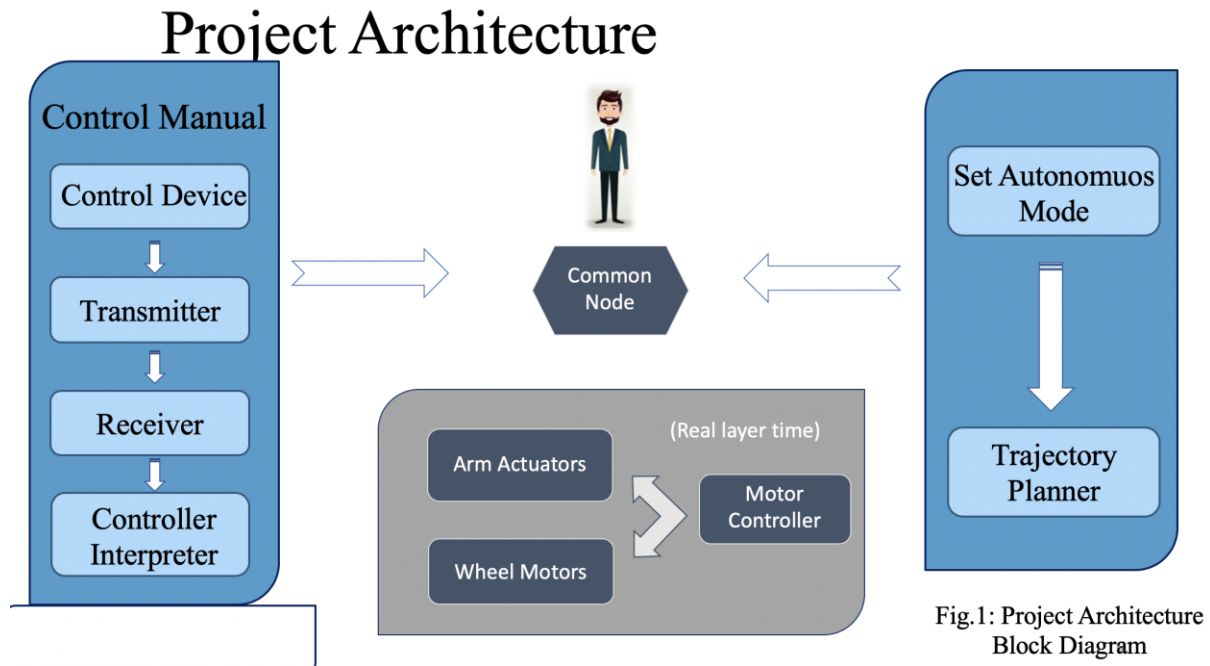
- Search and read about the project by searching for similar projects and other literature to get more knowledge and collect information as much as needed.
- Plan for project by identifying the needed resources at PMU and local market.
- Prepare project management plan with list tasks, time limit and team member responsibilities.
- Identify project subsystems and alternatives to implement each one.
- Design the chassis and identify the needed components to implement design.
- Collect and fabricate the required items to build the chassis and the arm.
- Design the arm and identify appropriate microcontroller and display.
- Build the arm and the chassis.
- Program the required codes to operate the autonomous mode of the rover.

- Integrate and test the chassis and the arm, and make necessary calibration and improvements.

Phase 2 (Term 2, ASSE III):

- Design other subsystems (Solar cells, Communication system) and implement them using appropriate components.
- Integrate solar tracking and communications sub-systems with the main system.
- Write the programming codes of the remote control system of the rover and the arm.
- Test and analyze each subsystem and make necessary improvements.
- Integrate all subsystems and perform final testing.
- Write final report and presentation.

A block diagram for the smart rover is shown in Fig. 3.



**Figure 3**

Figure 3 shows the project architecture. We can see the common node and it gathers the control manual and the autonomous mode.

### 3.3 Product Subsystems and Components

We started by the calculation part, as the first step.

#### Calculation part:

First, we need to find the estimated weight value for:

- Chassis.
- 6 DC motors.
- Robotic arms.
- Solar panel.

Such results yield to the value of torque. Also, it is very important to choose the best DC motors. Then, we need to choose the best solar panel that can charge the battery and have lighter weight and range current between 1-2 A.

%	Chassis	6 DC motor	Robotic arms	Solar panel
Weight	3-2 kg	1.26 kg	1kg	376g/0.8lb

Table 1.

**Total weight:**

6 -7 kg

$$Power = Torque \times RPM$$

$$Force (F) = m \times a$$

$$F = 6kg \times \left(9.8 \frac{m}{s^2}\right) = 58.8 N$$

If we choose the wheel in picture ( $rw$ ) = 65 mm

The torque defined in equation is

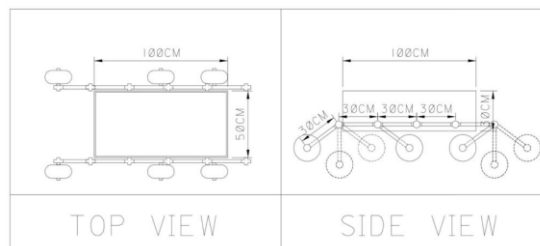
$$Tw = F \times rw$$

$$Tw = 58.8 \times \frac{65mm}{1000} = 3.822 N.m$$

PMDC motors--- type

**3.3.1 Product Subsystem 1: Choosing the Components**

For the chassis we had to simulate the chassis in AutoCAD program in order to verify our selection as shown in Figure 4



**Figure 4**

After verifying our design for the chassis, we had to choose the right materials to create it. With that being said, we had to choose a strong material that is also light in order to make the rover go over obstacles and prevent stalling. As a result, we select this chassis 4

Type for the wheels:



**Figure 5**

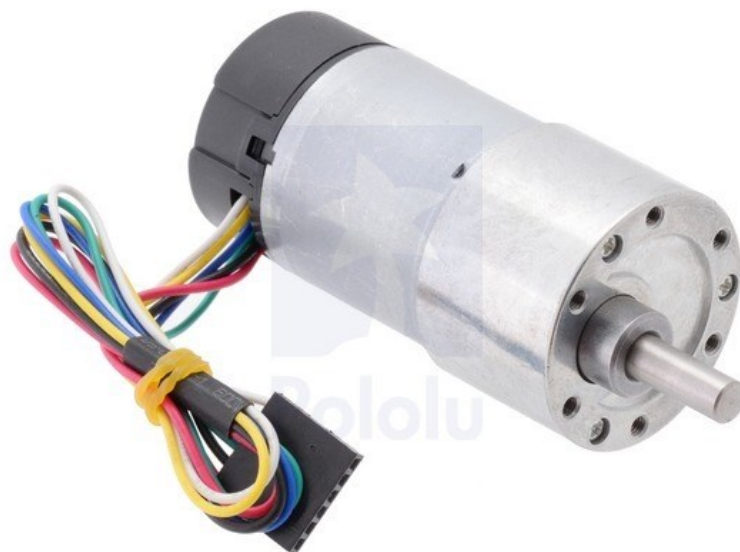
Figure 5 shows the type of wheels that were used for the Rover.

- Recommended for 3 to 10 kg robots (4 or 6 wheel usage recommended).

**Diameter:** 130 mm

**Thickness:** 59 mm

**Weight:** 173 gm (each wheel with mounting hub)



[www.pololu.com](http://www.pololu.com)

**Figure 6**

Figure 6 shows the motor that were used for the Rover.

## 2. Metal Gearmotor 37Dx73L mm with 64 CPR Encoder (Spur Pinion)

### Dimensions:

**Table 2.**( Dimensions)

Size:	<b>37D × 72.5L mm</b>
Weight:	210 g
Shaft diameter:	6 mm

### General specifications:

**Table 3.** ( General specifications)

Gear ratio:	<b>131.25:1</b>
No-load speed @ 12V:	76 rpm
No-load current @ 12V:	0.15 A
Stall current @ 12V:	5.5 A
Stall torque @ 12V:	45 kg·cm
Max output power @ 12V:	6 W
No-load speed @ 6V:	38 rpm
No-load current @ 6V:	0.1 A
Stall current @ 6V:	3.0 A
Stall torque @ 6V:	28 kg·cm

### Performance at maximum efficiency:

**Table 4.** ( Performance at maximum efficiency)

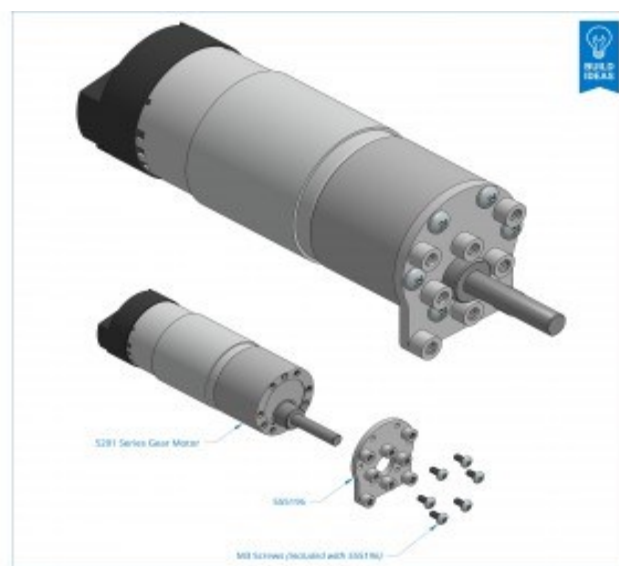
Max efficiency @ 12V:	<b>45%</b>
Speed at max efficiency:	66 rpm
Torque at max efficiency:	6.0 kg·cm
Current at max efficiency:	0.74 A
Output power at max efficiency:	4.1 W

### General specifications:

**Table 5.** ( General specifications)

Lead length:	<b>20 cm</b>
Encoders?:	<b>Y</b>
Encoder resolution:	<b>64 CPR</b>

3. 5201 Series, 53:1 Ratio, 105 RPM Spur Gear Motor w/Encoder:



**Figure 7( The Motor)**

Stalling this gear motor could cause gear damage.

\*At Nominal Voltage

Voltage (Nominal)	12V
Speed (No Load)*	105 RPM
Current (No Load)*	0.25A
Current (Stall)*	9.2A
Torque (Stall)*	720 oz-in
Gear Ratio	53.475:1
Gear Material	Metal
Gearbox Style	Spur
Motor Type	DC
Motor Brush Type	Brushed
Output Shaft Diameter	6mm
Output Shaft Style	d-shaft
Electrical Connection	Motor: 3.5mm Bullet Connectors , Encoder: 4-Pos JST XH
Wire Length	18.50in (470mm)
Product Weight	339g
Encoder: Cycles Per Revolution (Motor Shaft)	7 (Rises of Ch A)
Encoder: Cycles Per Revolution (Output Shaft)	374.325 (Rises of Ch A)
Encoder: Countable Events Per Revolution (Motor Shaft)	28 (Rises & Falls of Ch A & B)
Encoder: Countable Events Per Revolution (Output Shaft)	1,497.325 (Rises & Falls of Ch A & B)
Encoder Type	Relative, Quadrature
Encoder Sensor Type	Magnetic (Hall Effect)
Encoder Sensor Input Voltage Range	3.3 - 5VDC

**Figure 8.**

Figure 8 shows the motor's data sheet.

**Solar Panel:**

The solar panel that were used to recharge the battery As shown in Figures 9-10.



**Figure 9.(solar panel flexibility)**



**Figure 10( solar panel dimensions)**

4. XINPUGUANG Flexible Solar Panel, 10 W 12 V Monocrystalline Silicon PV Module with Alligator Clip Cable for RVs Car Boats, Remote Transmitters, Battery Charging, Electric Gate Openers (12v or 18v).

- High efficiency 10 W monocrystalline solar panel manufactured to the highest quality and performance standards, excellent performs even in weak light.
- This Monocrystalline Photovoltaic PV modules can withstand high wind-pressure, snow loads and extreme temperatures. It is waterproof and portable.
- The solar cells are encased and protected by a durable & transparent outer frame, backside junction box is sealed and waterproof.
- Size: 440\*190\*3 mm/17.3"x7.5"x0.12", Package weight: 376 g/0.8 lb. The 10 W monocrystalline solar panel is lightweight and easy to transport, hang, remove and storage.
- Flexible Solar Panel can be curved to a maximum 30 degree and mounted on an RV, boat, cabin, tent, car, trucks, trailers or any other irregular surface.



**Figure 11(shock absorbers)**



**Figure 12(Battery and shock absorbers)**

### ***3.3.2 Product Subsystem 2: Testing the Components***

For this, we will have to test all the components in order to implement it properly. We divide the tasks in order to be more sufficient and manage the time properly. We will test the components in the lab to test its capability and make sure it works as in the plan.

### 3.3.3 Product Subsystem 3: Bluetooth Control and Autonomous Mode

We will put everything together and start working in the Bluetooth control in order to generate the manual control mode. On the other hand, we also have to create the obstacle avoidance system using ultrasonic sensors with servo motors. After finishing, we have to integrate the both modes together into one system.

#### Motors:

In order to connect the motors and make it able to work, we had to look for motor drives that can take a current of 7 A. See Figure 13.



Figure 13

## Other Components

- Six DC motors
- 12 V and 18 Ah battery
- A number of six 25 mm wheels
- Two 14 cm shock absorbers for the front wheels
- Two 12 cm shock absorbers for the rear wheels
- Arduino mega, ultra sonic sensor, and servo motor

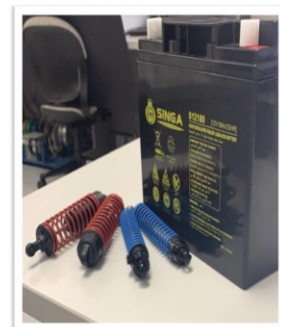


Figure 14

Figure 14 shows some of the components that were used for the Rover.

### **Autonomous Mode:**

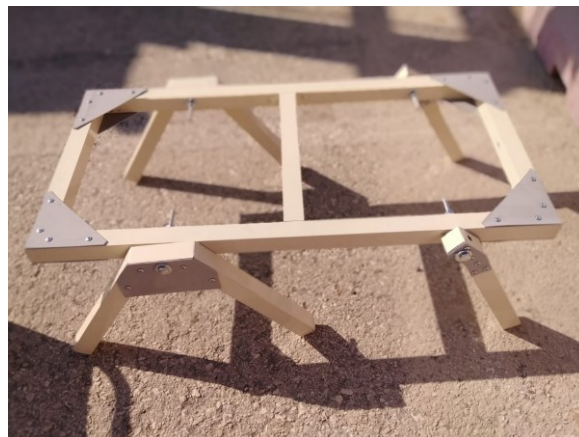
For the autonomous mode, we had to develop an obstacle avoidance system, and the best way is to use ultrasonic sensors with servo motors. See Figure 15



**Figure 15**

### **3.4 Implementation**

We started by fabricating the designed chassis in order to come up with the chassis that can hold all the subsystems for now and the next semester. With that being said, we created this chassis shown in Figure 16.



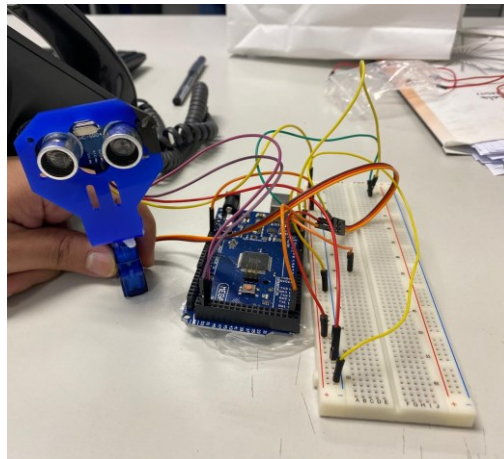
**Figure 16**

After that we put a base for our components as shown in Figure 17.



**Figure 17**

After that, we started testing the motors in the lab and test the ultrasonic sensors along with the servo motor as shown in Figure 18.



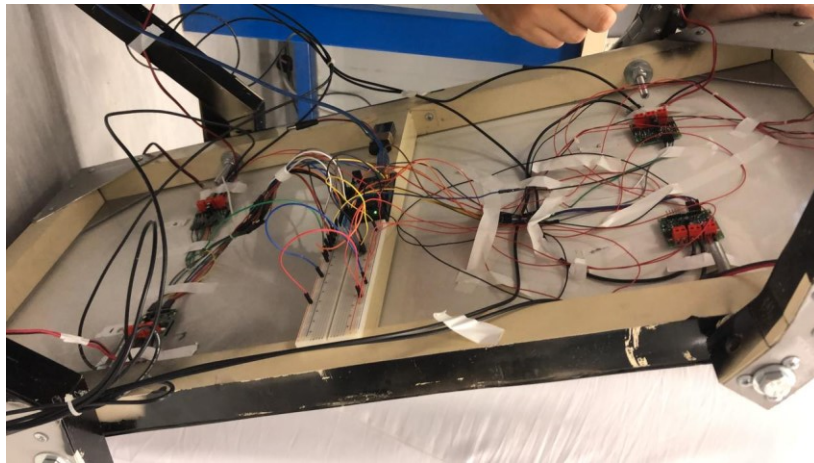
**Figure 18**

We verified all the components and started to put everything all together, while coding the needed program to reach our target for this semester. As a result, we started connecting the components as shown in Figure 19.

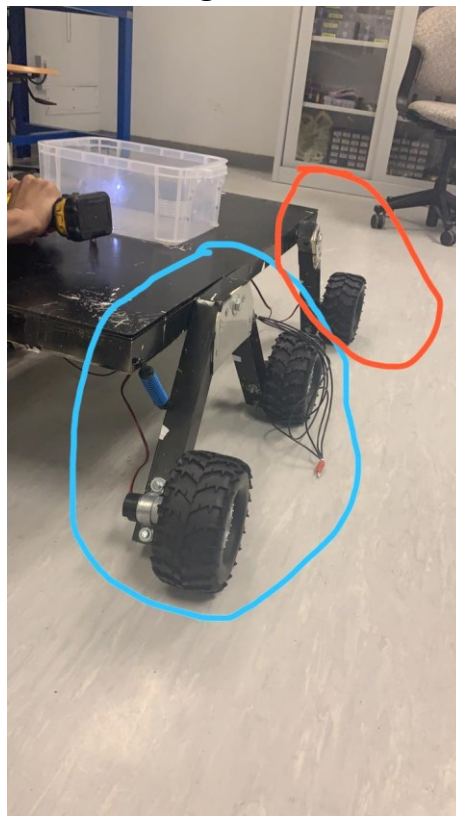


**Figure 19**

As shown in Figure 20, we connected the wires in the Arduino mega, then going to all other components.

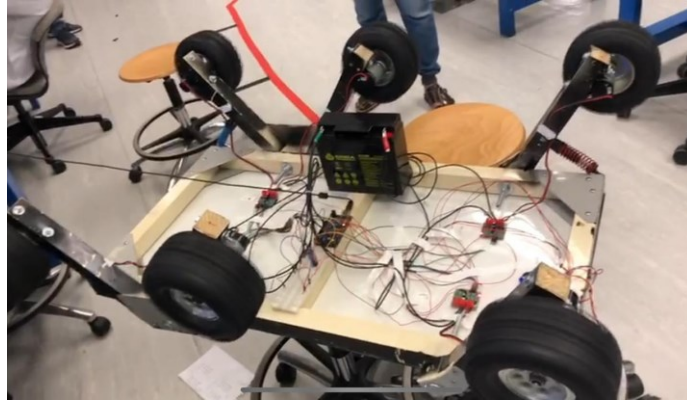


**Figure 20**



**Figure 21**

As shown in Figure 21, The blue area corresponds to the 2 motors with one motor drive and red area is the connection of one motor drive. In total, we used 4 motor drives. After that, we tested the motors and finally it worked all together.



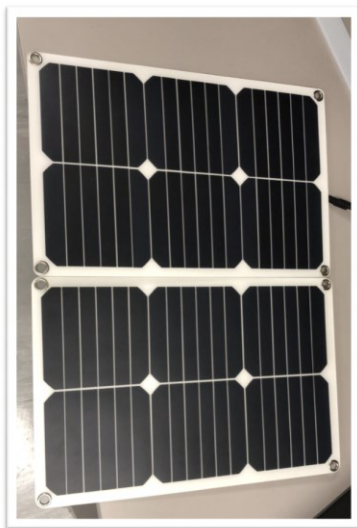
**Figure 22( The wheels' direction test)**

All this open us to new plans for the next semester in order to deliver our senior project.

#### **4. System Testing and Analysis**

##### **4.1**

### **Subsystem I (Tracking solar panel)**



#### **Subsystem Specification:**

##### **1. Solar Panel:**

- **18 W**
- **18 V**
- **1 A**

##### **2. Tracking System**

##### **3. Voltage Controller**

**Figure 23( Solar Panel that were used to recharge the battery)**

#### **Objectives**

- Creating sun tracking solar panel system.
- Charge the battery by solar power.

## Setup

As shown in Figure23, we used the material specified above.

## Results

We were able to create the stand and buy the servo motors for the tracking movement. In addition, we were able to write the needed code in order to make the subsystem work.

## 4.2

# Subsystem II (Robotic Arm)

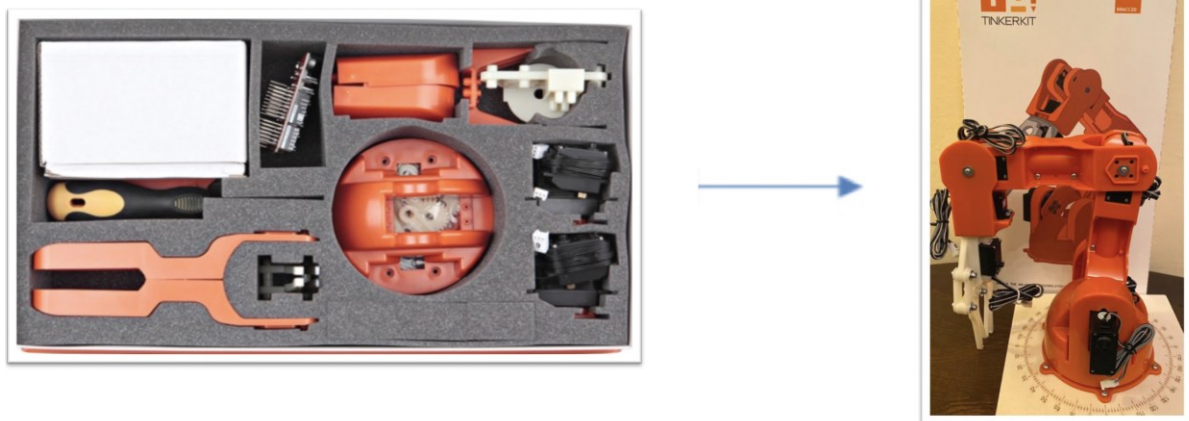


Figure 24

## Objectives

- Assemble and program a robotic arm.
- Pick samples.

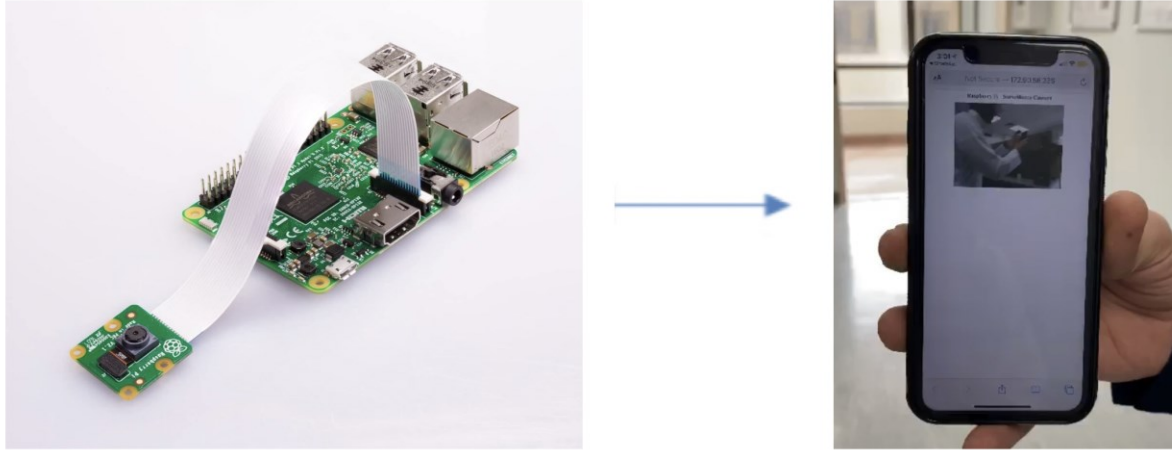
## Setup

As shown in Figure 24, we used the material specified above.

## Results

We were able to assemble the robotic arm as shown in Figure 24 in order to allow the movement. In addition, we were able to write the needed code in order to make the subsystem work.

## Subsystem III (Video Streaming)



**Figure 25**

### Objectives

- Programing Roseberry Pi board.
- Video Streaming.

### Setup

As shown in Figure 25 we used the material specified above. We had to connect the camera and learn about this new device.

### Results

We were able to program the Roseberry Pi board as shown in Figure 25 in order to make a video stream. In addition, we were able to make such feature remotely in order to make the control mode more efficient.

## 4.4 Overall Results, Analysis and Discussion

Overall, we were able to do all parts in the best manner. In addition, we had to test each subsystem to make sure that it works perfectly. Moreover, everything was perfect and working perfectly. All codes were written in order to make the subsystems work. We can say that all subsystems are ready to be used for the Rover.



**Figure 26**

As for the overall result, you can see in each subsystem that we managed to sufficiently almost make it ready for the assembling part. See Figure 26.

- **Manual Control Mode**

We were able to purchase the needed controlling device and by using XBee transmitter and receiver, we were able to create the long-distance controlling. In addition, for the long distance controlling, we thought that it would be hard to control the rover without video streaming. As a result, we added the video streaming as a bonus in our project. And as shown in the specific subsystem, we tested the function of the components separately after programming the part and completing it.

- **Autonomous Mode**

For this mode, we programmed ultrasonic sensors in order to detect the obstacles that we should avoid. We faced a major problem. The Arduino board failed to power this huge number of five ultrasonic sensors with servo motors. However, we managed to create an external power supply to power these components.

- **Sun Tracking Solar Panels**

As shown in the subsystem, we were able to find the suitable solar panels and design the required base for the tracking feature. Also, we managed to finish the coding part and make it ready. Nevertheless, we tested the panels specification to make sure that it does not contradict with our application.

- **Robotic Arm**

As shown in the subsystem, we managed to assemble and program the robotic arm to perform the required task which is collecting samples. We tested the robotic arm in order to make sure that it works properly before we assemble the rover body. As a result, we had to program it and check its function and see the ability to collect samples.

## 5. Project Management

### 5.1 Project Plan

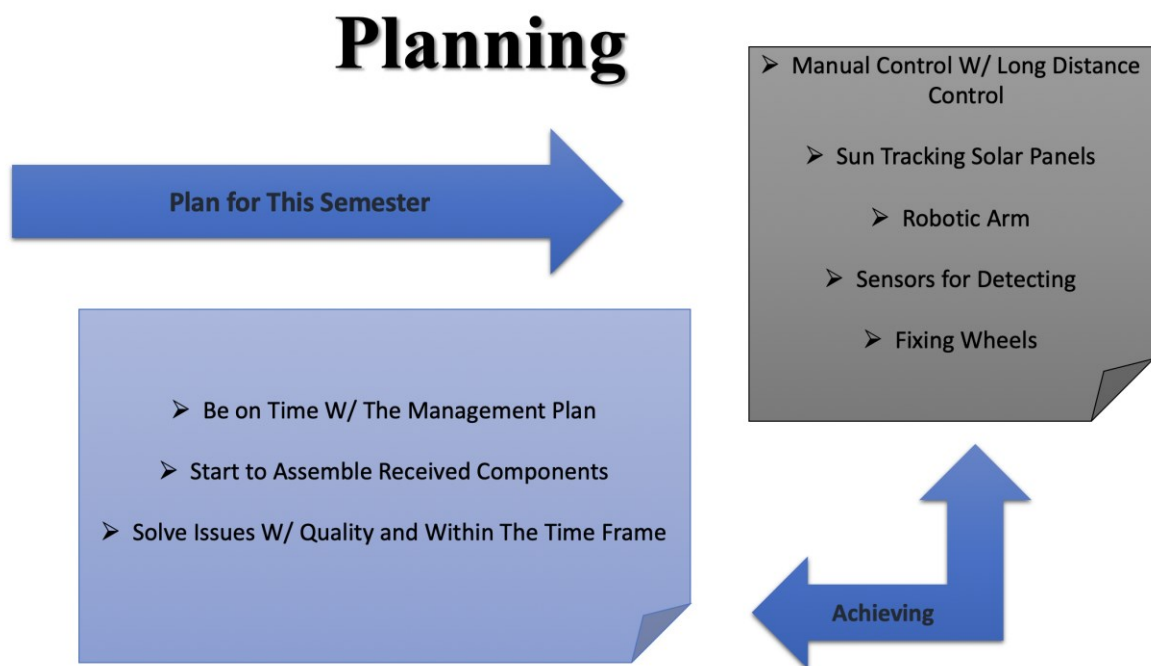


Figure 27( Project Plan)

### 5.2 Contribution of Team Members

Table 6(Contribution of Team Members)

Task	Omar	Saad	Bandar	Salman	Task Total
Search & acquire components	30%	20%	35%	15%	100%
Design Subsystems	25%	30%	20%	25%	100%

<b>Test Subsystems</b>	<b>30%</b>	<b>25%</b>	<b>15%</b>	<b>30%</b>	<b>100%</b>
<b>Write Reports &amp; Presentations</b>	<b>25%</b>	<b>25%</b>	<b>20%</b>	<b>30%</b>	<b>100%</b>

### 5.3 Project Execution Monitoring

- Meetings with Advisors

We were dedicated to the weekly meet with our advisor. As we know how important to take his opinion before we start working on the subsystem. Moreover, this helped us as we made sure of each and every step, in order to be more time managed and to keep our progress going.

- Team meetings

We meet almost every school day, because we had to discuss the subsystems and the needed components. We had to discuss our issues that we faced and try to look for a problem for it as a team. In addition, we were always connected with social media in order to be in touch with each other in every step.

- Other activities

We had to meet together in order to test subsystems and make sure that it is properly works in the manner that we desire. Nevertheless, this was a major key point, as we needed to make sure that we test the subsystem and make sure that we finished or found a solution for it before we go to the next required task. Consequently, in this point, we were lucky that our advisor was with us in the testing phase for subsystems.

### 5.4 Challenges and Decision Making

- **Wheels**

We faced a major setback in the wheels, because it tends to get stuck in the ground and negatively affect the rover movement because we could not find a good quality wheels in the market. As a result, we had to look for a more convenient solution for this problem and look for wheels in hardware markets.

- **COVID**

COVID negatively affects our progress with the major shutdown of university and other shops. In addition, our rover got stuck in the university.

### 5.5 Project Bill of Materials and Budget

Table 7 (Project Bill of Materials and Budget)

<b>Item</b>	<b>Quantity</b>	<b>Unit Cost (SR)</b>	<b>Subtotal</b>
Battery	1	150	150
Motor Drives	6	80	320
Chassis & Wheels	1	1000	1000
DC Motor	6	100	600
Solar Panel	2	150	300
Microcontroller	2	65	130
Servo Motor	2	100	200
Robotic Arm	1	800	800
			<b>Total= 3500 SR</b>

## **6. Project Analysis**

### **6.1 Life-long Learning**

- **XP**

We learned how to use XP transmitter and receiver in order to create out long distance controlling for the rover. As a result, we learned to program and write command for the control mode.

- **Raspberry Pi**

This was a new challenging topic for us, as we struggled in the beginning. However, with help of our advisor and the internet, we were able to create the video streaming and learn about this exciting board.

- **Sun Tracking**

In this part, we mostly learned how to program the servo motors to support the tracking by knowing the sun angle. As a result, we had to write the code to be programed to see in which place that the charging is maximum and make the servo motors support this.

### **6.2 Impact of Engineering Solutions**

Our senior project is going not only to impact the exploring and make it safer, but also will impact the whole globe with the new discoveries that it is going to find. Nevertheless, our project is a true valuable creation for the society and scientist all over the world with its countless function that would make our globe brighter for the new generations as a result of the new horizons that it would reach and enrich.

### **6.3 Contemporary Issues Addressed**

The major compelling problem that affected our progress was the COVID, since the major shutdown of almost everything. Also, we faced some problems with the components that we order since sometimes we have to order online that make the cost rise. Moreover, with some components, we faced many difficulties in order to purchase it as most of suppliers to ship it to Saudi.

## 7. Future Work and Limitation and Challenges

### 7.1 Future Work and Expected Final Prototype/Results

- Chassis that can go over rough terrain

We inspire our chassis design from NASA Mars rover. However, we could not test our chassis design in extremely rough terrain due to the sudden stop of COVID-19. In the last semester, we tested the design on a small obstacle and we improved it based on that test but we did not have the chance to test the modified design.

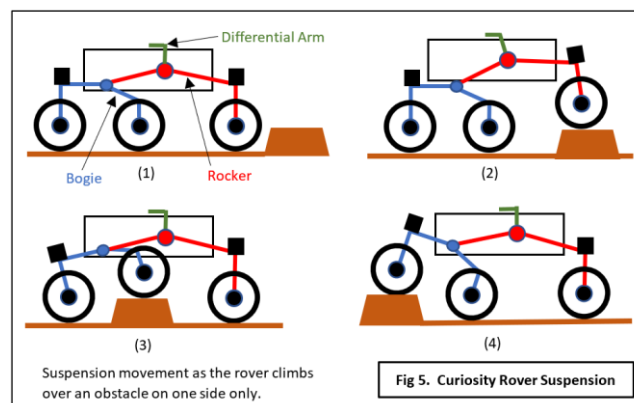


Figure.28: How the chassis can go in the rough terrain.

Hence, in the future, we would test the chassis capability to climb a staircase as an example of how rough terrain could be.

- Remotely controlled robotic arm

The robotic arm as a subsystem was not tested at all. We ordered the arm and assembled it to be ready for installation. Moreover, the code of operating the robotic arm was written but has been not tested due to an unexpected stop of COVID-19.



Figure29 (After)

Figures 28-29 shows the robotic arm before and after assemble

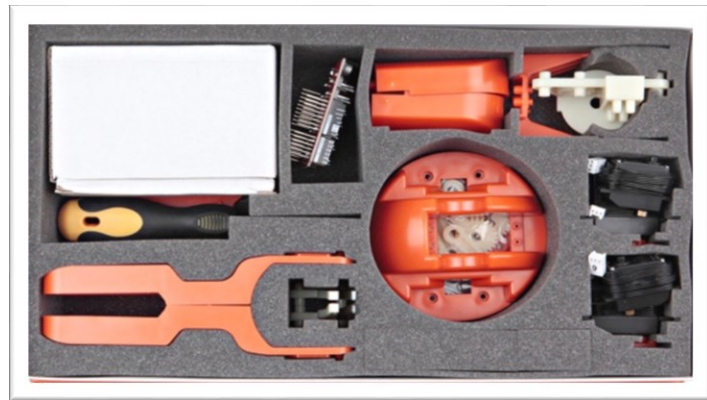


Figure28 (Before)

What we should do in the future is to install the robotic arm on the chassis and test the code to ensure it is working properly. Moreover, the arm may carry some sensors to get the reading from the surrounding.

- Remote Control Mode

We tested the remote control mode by Bluetooth. However, Bluetooth has a distance limitation, and to operate the rover on a far distance we have to install a different distance control system. Accordingly, we installed a Rosebery PI camera on the rover to monitor the rover path from far distance, and it was operated without and difficulties. In addition, we chose the Joystick as a distance control device but we did not test it.

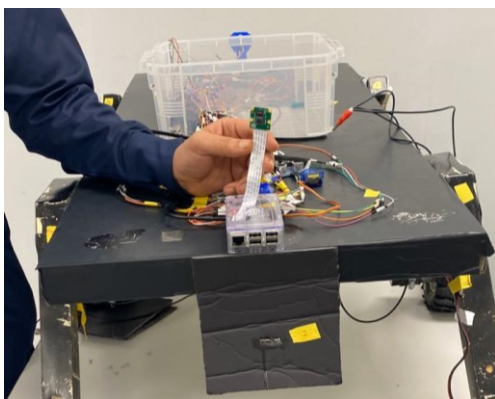


Figure 30: (Raspberry PI camera installed).

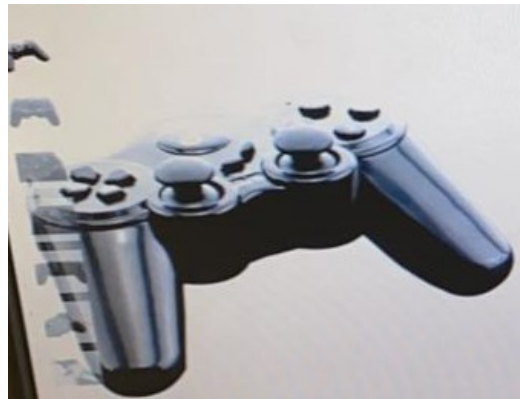


Figure 31: (Joy stick control device).

In the future, we should test the new remotely controlled system, and write the necessary code to operate the rover remotely.

- Solar panels with sun tracking feature to maximize battery charging

We ordered the solar panel and fabricate the frame which is going to be flexible to apply sun tracking feature. The code of sun tracking system was written but we could not test it due to the unexpected COVID-19 situation.



Figure 32: Solar sun ready to install on the rover.

The remaining is to install the servomotor (which will control the solar panel direction) and test the code to ensure it is working properly. Then, we can put the charge controller to control the battery recharging.

- Wheel

The wheels we ordered were not initially the expected size, so we bought a temporary wheel for testing purposes. Recently and just before the curfew due to COVID-19, we bought the new strong wheels to be the permanent wheels.



Figure 33: Temporary wheel installed in the rover.

For the future, we need to lathe the new wheels to fit into our 12 V DC motors and install them on the rover

- Sensors

We ordered an IMU sensor to balance the chassis but we did not do anything further due to the unexpected stop of COVID-19.



Figure 34: IMU sensor.

In the future, we may install the IMU sensor along with other sensors such as temperature sensor, humidity sensor, geological analyzing sensors, and distance sensor. The purpose of installing these different sensors is the main reason for the Curiosity Rover, exploring new areas hard to reach and collect the data from these remote areas.

## 7.2 Limitation and Challenges

COVID-19 played a role in not completing the Curiosity Rover. It was a real challenge, which did not let us meet as a group to complete the work and sharing the ideas. We were in a hard situation because we had most of the components ready, but the issue was that the Rover was at PMU. Due to COVID-19 and the quarantine, we were not able to go to PMU and collect the Rover. In addition, during this situation we were trying to write the codes for the ultrasonic sensors, robotic arm and the sun tracking solar panel, but writing the codes without testing these codes on the Rover makes it so hard on us. In fact, in some situations and from time to time, we have to check the wiring to write the correct code. In addition, all the workshops that we buy the materials from were closing during the quarantine due to the COVID-19. Consequently, we were not able to look for a new wheels. We were trying our best with this situation. Moreover, the faculty were helpful and they did understand our situation. They were trying to give us some ideas and suggestions to work at home. The work was via online such as writing reports and doing presentations. We were also having a weekly meeting with the course instructor to have a feedback on our progress and to hear his suggestions. In one word, despite all the challenges that we have faced because of COVID-19, we were trying our best to complete the Curiosity Rover on the best manner.

## **8. Conclusions and Future Recommendations**

### **8.1 Conclusions**

The Curiosity Rover can be developed in different modes of controlling (Manual and Autonomous modes). In our project, we consider doing our project in a more efficient way and to reach nearly all our specifications. Until now, we tested most of the electronics functionality; during this testing, we faced some difficulties especially with using multiple ultrasonic sensors such as that the Arduino board cannot supply more current. In this problem, we tried to use an external source to supply the ultrasonic sensors. Furthermore, there are many challenges during our work in the previous semester and this semester such as choosing the proper motor that can handle the rover and has an efficient torque. Also, we tried to fix the wheels and replace the old ones but unfortunately, during pandemic we couldn't. The most challenge part was the coding and you need to work hard to write the code for each part. Overall, in our project, we

learned many things in both electrical and mechanical since our project needs both to complete it. We improved our knowledge in the C++ language since our project mainly depends on coding.

## **8.2 Future Recommendations**

- Start as early as possible.
- Be connected with your team.
- Make sure you select the suitable components for your application.
- Test each and every subsystem .

## 9. References

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## Appendix A: Progress Reports



**Prince Mohammad Bin Fahd University (PMU)**  
Department of Electrical Engineering

**Design Methodology & Project Management**  
Instructor: Dr. Samir El Nakla

**Fall 2019-20**

**Project Proposal**

**The Curiosity Rover  
(Smart Rover for Exploring)**

**Team:**

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**Project Advisor(s)**

Mr. Ahmed Abul Hussein

Date submitted: 18 Sep 2019

Submitted to  
Dr. Samir El Nakla

## **1. Project Definition:**

Smart Rover for Exploring is a robotic vehicle remotely controlled or fully autonomous backed up with sun tracking solar panels for on-board self-battery charging. The rover will be designed to move across rough terrain that may otherwise cause risks and danger for individuals. Smart rover will also be able gather data on environmental parameters and collect sample of a wanted object using a robotic arm.

## **2. Project Objectives:**

- i. Learn about robotic vehicles are using in space exploration.
- ii. Design a smart and automated rover.
- iii. Build and program the rover.
- iv. Implement sun tracking solar panels for on-board self-battery charging.

## **3. Project Specifications:**

- a. Chassis that can go over rough terrain.
- b. Remotely controlled robotic arm.
- c. Can be used in remote control mode, or it can go in autonomous mode.
- d. Solar panels with sun tracking feature to maximize battery charging.
- e. Multiple 12 volts motors (one in each wheel) to provide more power.
- f. Sensors to detect obstacles and avoid them in autonomous mode.

## **4. Introduction:**

Robotics occupies a special place in the arena of interactive technologies. It combines sophisticated computation with rich sensory input in a physical embodiment that can exhibit tangible and expressive behavior in the physical world. What is an appropriate first role for intelligent human-robot interaction in the daily human environment? The time is ripe to address this question. Robotic technologies are now sufficiently mature to enable interactive, competent robot artifacts to be created. The study of human-robot interaction, while fruitful in recent years, shows great variation both in the duration of interaction and the roles played by human and robot participants. In cases where the human caregiver provides short-term, nurturing interaction to a robot, research has demonstrated the development of effective social relationships. Nevertheless, The rover's size and shape are born from practical constraints regarding the home environment together with the goal of emulating the aesthetics of the exploratory rovers. Users should be able to easily manipulate the rover physically. Also, the rover must be small enough to navigate cramped spaces and large enough to traverse outdoor, grassy terrain and curbs. There are some benefits to have a rover for example:

- It can goes to a places that human do not get hurt.
- It can used to take sample by using a robotic arm.
- It can goes to a rough surfaces.
- The rover can be controlled or it can be in automated mode.

## 5. Applications

The rover can be used:

- i. It can use to take sample and help scientist in their research.
- ii. It is very helpful for exploring and discovering purposes.
- iii. It can navigate over rough surfaces and terrain.
- iv. It does the required tasks while consuming green energy from the sun tracking solar panels.

## 6. Design Methodology

We have divided the project into several parts to make it easy to handle and test. The main part of the project is to build a rover and insure it is function correctly.

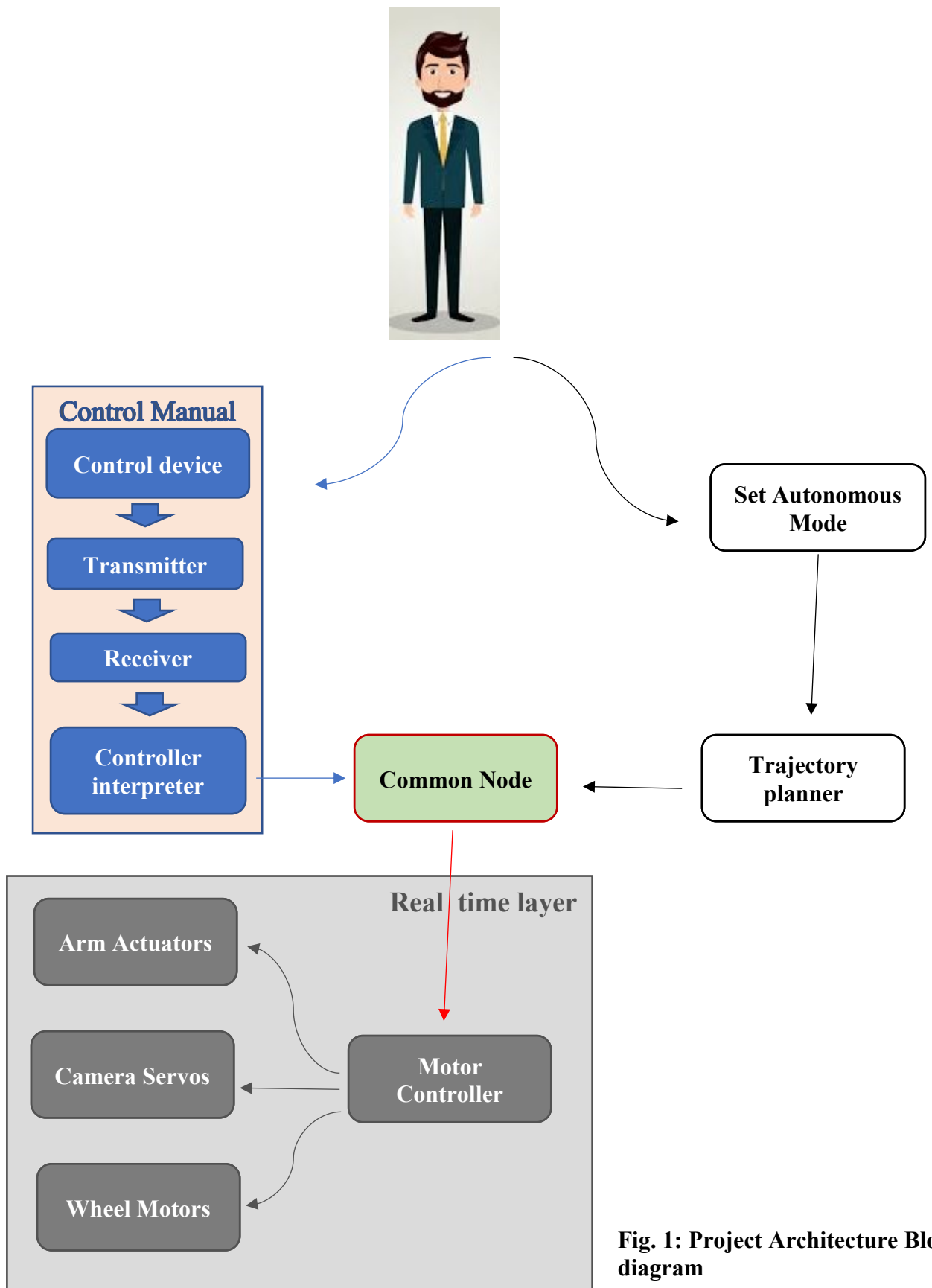
### Phase 1 (Term 1, Design M.):

- Search and read about the project by searching for similar projects and other literature to get more knowledge and collect information as much as needed.
- Plan for project by identifying the needed resources at PMU and local market.
- Prepare project management plan with list tasks, time limit and team member responsible.
- Identify project subsystems and the alternatives ways to implement each one.
- Design the chassis and identify the needed components to implement design.
- Collect and fabricate the required items to build the chassis and the arm.
- Design the arm and identify appropriate microcontroller and display.
- Build the arm and the chassis.
- Program the required codes to operate the autonomous mode of the rover
- Integrate and test the chassis and the arm, and make necessary calibration and improvements.

### Phase 2 (Term 2, ASSE III):

- Design other subsystems (Solar cells, Communication system) and implement using appropriate components.
- Integrate solar tracking and communications sub-systems with the main system.
- Write the programing codes of the remote control system of the rover and the arm.
- Test and analyze each subsystem and make necessary improvements.
- Integrate all subsystems and perform final testing.
- Write final report and presentation.

A block diagram for the smart rover is shown in Fig. 1. See next page.



**Fig. 1: Project Architecture Block diagram**

## 7. Budget Estimate

The following is an **initial** list of components required to implement our project and the total **estimated** budget: approximate: these are the main components:

No.	Description	Quantity	Unit Cost (SR)	Total Cost (SR)
1	Microcontroller	2	65	130
2	Battery	1	300	300
3	Servo Motor	2	100	200
4	Chassis	1	1500	1500
5	Solar Panel	1	450	450
6	Remote Control	1	150	150
<b>Totals</b>				<b>2730 SR</b>



**Prince Mohammad Bin Fahd University (PMU)**  
Department of Electrical Engineering

**Design Methodology & Project Management**  
Instructor: Dr. Samir El Nakla

**Fall 2019-2020**

### Progress Report

**The Curiosity Rover  
(Smart Rover for Exploring)**

#### **Team:**

Omar Yahya 201502345  
Bandar Albalawi 201101356  
Saad Alnassar 201500439  
Salman Alsunaid 201602839

#### **Project Advisor(s)**

Mr. Ahmed Abul Hussein

Date submission: 15 Oct 2019

Submitted to  
Dr. Samir El Nakla

In our progress report we want to highlight the main things we have worked on in the past weeks. First of all, we signed with our advisor and together we chose our topic to be The Curiosity Rover (Smart Rover for Exploring). Although, in every step we had to take our advisor opinion in order to be sure about it. In addition, we started to work in our proposal and we submitted it in the due date. Nevertheless, the proposal consist of the main points and specs for our project including an estimated budget as submitted. After that, we finished the literature review to know about other previous designs and to check the main points for designing our rover. We had to include the main criteria and requirements specified by our instructor. Moreover, we started working on our midterm presentation, however we still did not manage to finish it yet. Finally, we worked on the needed calculation for our rover design.

**Calculation part:**

First, we need to find the approximation weight value for:

- Chassis.
- 6 DC motor
- Robotic arms
- Solar panel.

After that depend in the result it will tell us the approximation value of torque, also it is very important to choose the best Dc motors. Then we need to choose the best solar panel that can charge the battery and have lighter weight and range current between 1-2 A.

%	Chassis	6 DC motor	Robotic arms	Solar panel
<b>Weight</b>	3-2 kg	1.26 kg	1kg	376g/0.8lb

**Total weight:**

6 -7 kg

$$Power = Torque \times RPM$$

$$Force (F) = m \times a$$

$$F = 6kg \times \left(9.8 \frac{m}{s^2}\right) = 58.8 N$$

If we choose the wheel in picture ( $rw$ ) = 65 mm

The torque defined in equation is

$$Tw = F \times rw$$

$$Tw = 58.8 \times \frac{65mm}{1000} = 3.822 N.m$$

PMDC motors--- type

Type for the wheels:



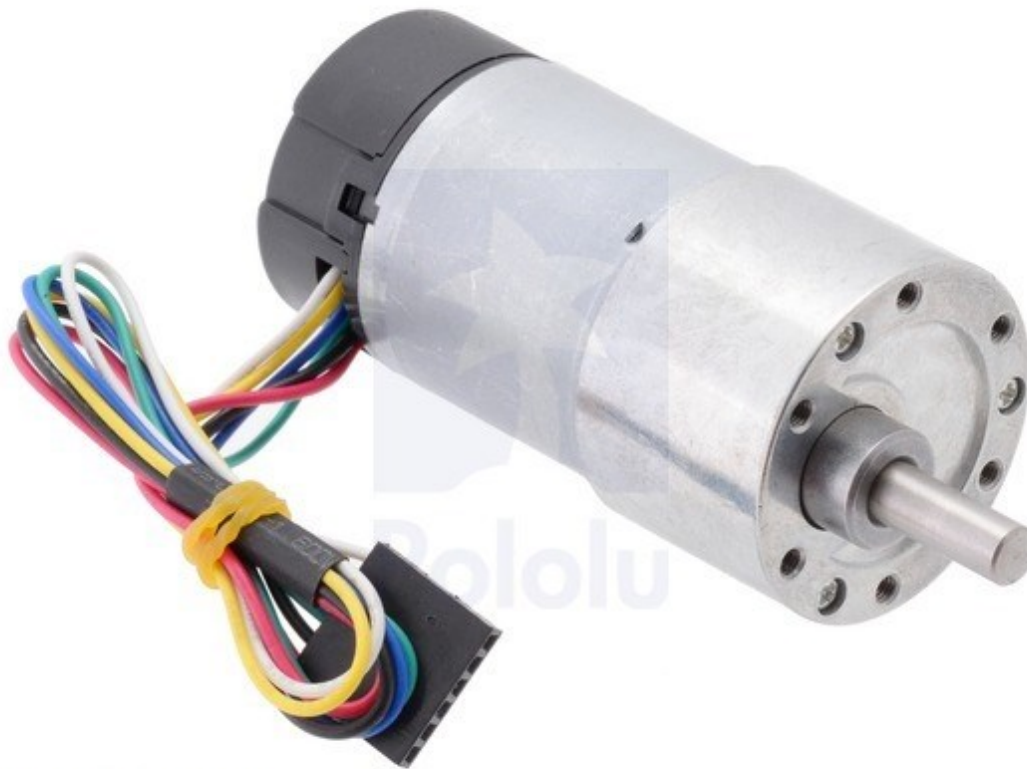
**JSUMO**  
www.JSumo.com

- Recommended for 3 to 10 Kg robots. (4 or 6 wheel usage recommended)

**Diameter:** 130mm

**Thickness:** 59mm

**Weight:** 173 gr (each wheel with mounting hub)



[www.pololu.com](http://www.pololu.com)

## 5. Metal Gearmotor 37Dx73L mm with 64 CPR Encoder (Spur Pinion)

### Dimensions

**Size:** 37D × 72.5L mm<sup>1</sup>

**Weight:** 210 g

**Shaft diameter:** 6 mm<sup>2</sup>

### General specifications

**Gear ratio:** 131.25:1

**No-load speed @ 12V:** 76 rpm

**No-load current @ 12V:** 0.15 A

**Stall current @ 12V:** 5.5 A<sup>3</sup>

**Stall torque @ 12V:** 45 kg·cm<sup>3</sup>

**Max output power @ 12V:** 6 W

**No-load speed @ 6V:** 38 rpm<sup>4</sup>

**No-load current @ 6V:** 0.1 A<sup>4</sup>

**Stall current @ 6V:** 3.0 A<sup>5</sup>

**Stall torque @ 6V:** 28 kg·cm<sup>5</sup>

#### **Performance at maximum efficiency**

**Max efficiency @ 12V:** 45 %

**Speed at max efficiency:** 66 rpm

**Torque at max efficiency:** 6.0 kg·cm

**Current at max efficiency:** 0.74 A

**Output power at max efficiency:** 4.1 W

#### **General specifications**

**Lead length:** 20 cm<sup>6</sup>

**Encoders?:** Y

**Encoder resolution:** 64 CPR

;



solar panel



6. XINPUGUANG Flexible Solar Panel, 10W 12V Monocrystalline Silicon PV Module with Alligator Clip Cable for RVs Car Boats, Remote Transmitters, Battery Charging, Electric Gate Openers (12v or 18v)

- High efficiency 10W monocrystalline solar panel manufactured to the highest quality and performance standards, excellent performs even in weak light.
- ✓ This Monocrystalline Photovoltaic PV modules can withstand high wind-pressure, snow loads and extreme temperatures. It is waterproof and portable.
- ✓ The solar cells are encased and protected by a durable & transparent outer frame, backside junction box is sealed and waterproof.
- ✓ Size: 440\*190\*3mm/17.3"x7.5"x0.12", Package weight: 376g/0.8lb. The 10W monocrystalline solar panel is lightweight and easy to transport, hang, remove and storage.
- ✓ Flexible Solar Panel can be curved to a maximum 30 degree and mounted on an RV, boat, cabin, tent, car, trucks, trailers or any other irregular surface.



Prince Mohammad Bin Fahd University (PMU)  
Department of Electrical Engineering

**Design Methodology & Project Management**  
Instructor: Dr. Samir El Nakla

Fall 2019-20

### Project Plan

#### **The Curiosity Rover (Smart Rover for Exploring)**

##### **Team:**

Omar Yahya 201502345  
Bandar Albalawi 201101356  
Saad Alnassar 201500439  
Salman Alsunaid 201602839

##### **Project Advisor(s)**

Mr. Ahmed Abul Hussein

Submitted to  
Dr. Samir El Nakla

### **Introducing**

In this paper we are summarizing the plan of creating the curiosity rover which is a smart rover for exploring purposes. In addition, after discussing the details with our advisor we come up with this plan.

### **First Semester**

#### **Task 1: calculation & parts**

We already started with the working on the Calculation part:

First, we approximate the weight value for:

- Chassis.
- 6 DC motor
- Robotic arms
- Solar panel

After that depend in the result it will tell us the approximation value of torque, also it is very important to choose the best Dc motors. Then we need to choose the best solar panel that can charge the battery and have lighter weight and range current between 1-2 A.

%	Chassis	6 DC motor	Robotic arms	Solar panel
Weight	3-2 kg	1.26 kg	1kg	376g/0.8lb

Total weight:

**6 -7 kg**

Power = Torque \* RPM

Force (F) = m \* a

6 kg \* 9.8 m/s<sup>2</sup> = 58.8 N

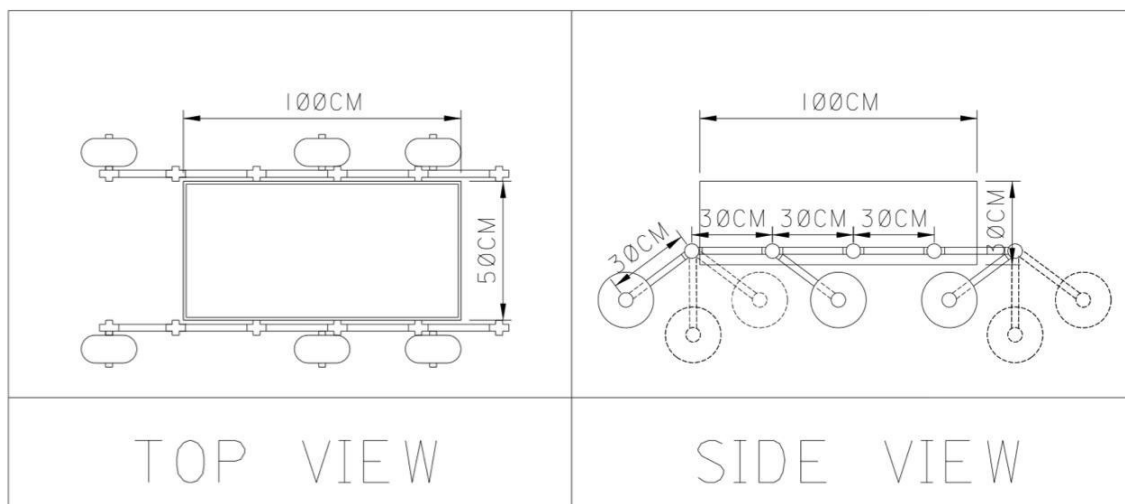
If we choose the wheel in picturte (rw)= 65mm

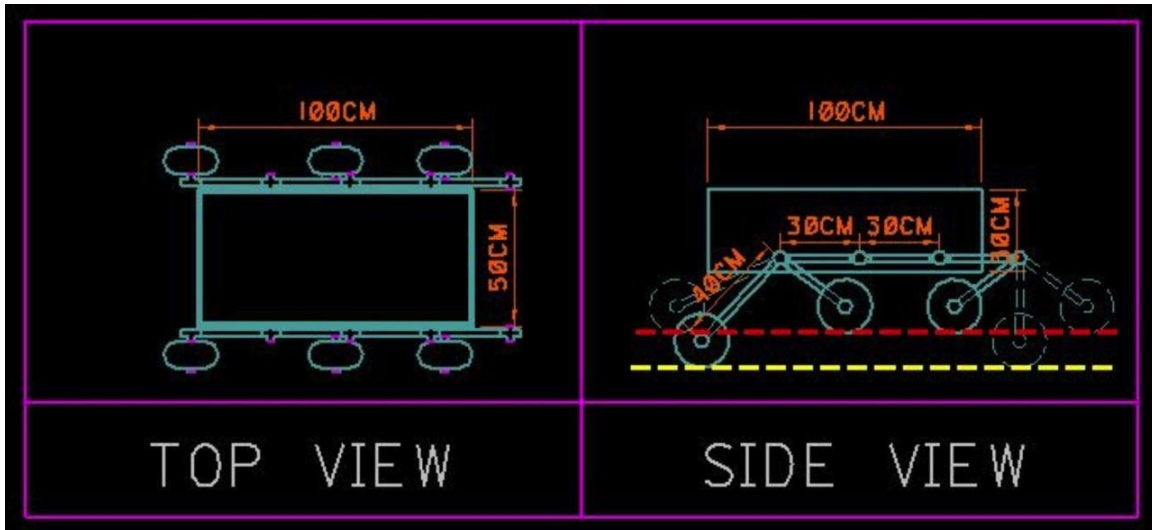
The torque define in equation

$T_w = F * r_w$

58.8 \* 0.065m = 3.822 N.

### Chassis





We picked the design of the chassis, and used some simulations programs in order to come up with design. Nevertheless, this chassis will provide the needed flexibility in order to climb and go over rough terrains.

Wheels

Type for the wheels:



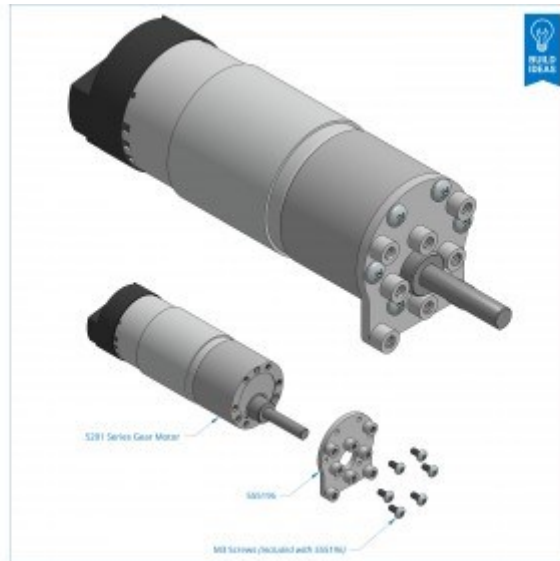
Here is the wheels Recommended for 3 to 10 Kg robots. (4 or 6 wheel usage recommended)

Diameter: 130mm  
Thickness: 59mm  
Weight: 173 gr (each wheel with mounting hub)

**Motor**

7. 5201 Series, 53:1 Ratio, 105 RPM Spur Gear

# Motor w/Encoder

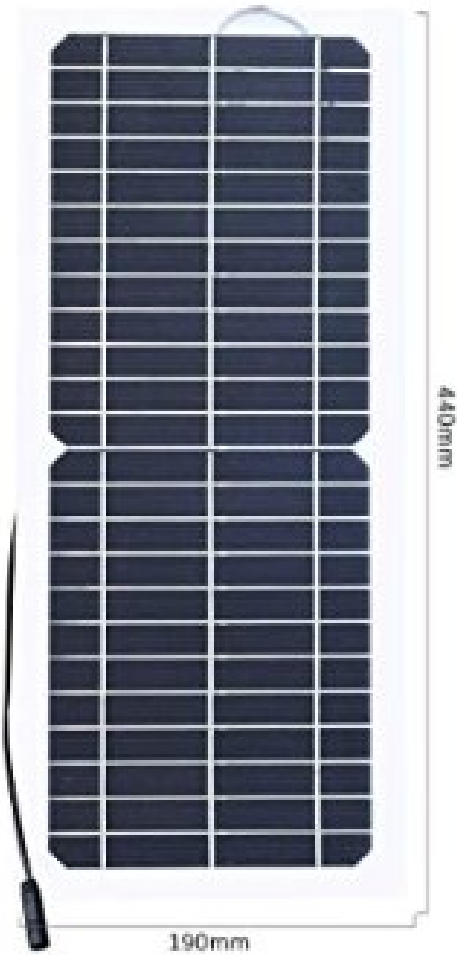


Stalling this gear motor could cause gear damage.

\*At Nominal Voltage

Voltage (Nominal)	12V
Speed (No Load)*	105 RPM
Current (No Load)*	0.25A
Current (Stall)*	9.2A
Torque (Stall)*	720 oz-in
Gear Ratio	53.475:1
Gear Material	Metal
Gearbox Style	Spur
Motor Type	DC
Motor Brush Type	Brushed
Output Shaft Diameter	6mm
Output Shaft Style	d-shaft
Electrical Connection	Motor: 3.5mm Bullet Connectors , Encoder: 4-Pos JST XH
Wire Length	18.50in (470mm)
Product Weight	339g
Encoder: Cycles Per Revolution (Motor Shaft)	7 (Rises of Ch A)
Encoder: Cycles Per Revolution (Output Shaft)	374.325 (Rises of Ch A)
Encoder: Countable Events Per Revolution (Motor Shaft)	28 (Rises & Falls of Ch A & B)
Encoder: Countable Events Per Revolution (Output Shaft)	1,497.325 (Rises & Falls of Ch A & B)
Encoder Type	Relative, Quadrature
Encoder Sensor Type	Magnetic (Hall Effect)
Encoder Sensor Input Voltage Range	3.3 - 5VDC

## Solar Panel



8. XINPUGUANG Flexible Solar Panel, 10W 12V

# Monocrystalline Silicon PV Module with Alligator Clip Cable for RVs Car Boats, Remote Transmitters, Battery Charging, Electric Gate Openers (12v or 18v)

- High efficiency 10W monocrystalline solar panel manufactured to the highest quality and performance standards, excellent performs even in weak light.
- ✓ This Monocrystalline Photovoltaic PV modules can withstand high wind-pressure, snow loads and extreme temperatures. It is waterproof and portable.
- ✓ The solar cells are encased and protected by a durable & transparent outer frame, backside junction box is sealed and waterproof.
- ✓ Size: 440\*190\*3mm/17.3"x7.5"x0.12", Package weight: 376g/0.8lb. The 10W monocrystalline solar panel is lightweight and easy to transport, hang, remove and storage.
- ✓ Flexible Solar Panel can be curved to a maximum 30 degree and mounted on an RV, boat, cabin, tent, car, trucks, trailers or any other irregular surface.

## Task 2: Assembling

In this task we will make the chassis and assemble it all together. After that, we will have ordering the needed material:

- Wheels
- Sensors
- Arduino mega
- Wires
- Batteries
- Other needed materials

After ordering these components we will start assembling the chassis and put it all together in order to proceed in the next task.

## Task 3: Autonomous mode & line following

For this subsystem we will use Arduino mega and start using our knowledge in programming to make our rover go in the autonomous mode also with line following and obstacles avoiding. In this subsystem we will have to connect multiple number of sensors to follow lines and also detect obstacles. With that being said, this is the final subsystem in the first semester.

## Second Semester

For the second semester there will be three main subsystems.

### Task 1: manual controlling mode & robotic arm

In this subsystem we will program the rover to work in the manual control mode to be controlled by a remote control. In addition, we have to work in the robotic arm. As a result, we will get a 3 DOF robotic arm and connect it in the chassis. Moreover, we will connect it to the processor and write the code to program it to work remotely by the remote control.

### Task 2: sun tracking solar panels and video streaming

In this Subsystem we will connect the solar panel and program it to follow the sun. Nevertheless, this feature will maximize the effectiveness for charging the batteries with solar power. Also, we will work in the video streaming for remotely streaming. In addition, we will use raspberry bi camera to develop this feature.

### Task 3: detecting sensors

In the final subsystem we will add some survival sensors in order to make our rover sufficient for exploring. As a result, we will add sensors like temperature sensors, gas sensors, and other important sensors. Also, the reading of these sensors will be visible at an LCD monitor connected in the rover.

### Plan:

The Curiosity Rover							Design Methodology & PM		Fall 2019/2020										
Saad Al Nassar 201500439							Project PLAN												
Salman Alsunaid																			
Bandar Albalawi 201101356							Instructor: Dr. Samir El-Nakla												
Omar Yahya 201502345							Period Highlight: 1												
Team mbr							Actual (beyond plan) % Complete (beyond plan)												
ACTIVITY	PLAN START	PLAN DURATION	Assigned To	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE	Periods (Weeks 1-15)												
Form teams	1	1	ALL	1	1	100%	█												
Select topic & advisor	2	1	ALL	2	2	100%	█	█											
Write proposal and plan	2	1	ALL	2	2	100%	█	█											
Background research & PPT1	3	2	ALL	3	2	100%	█	█											
Search and acquire components	3	3	ALL	3	4	100%	█	█	█										
Design subsystem 1 (building Rover	4	3	ALL	4	4	70%	█	█	█	█									
Test subsystem 1	5	4	ALL	5	4	30%	█	█	█	█	█								
chassis	5	2	ALL	5	3	80%	█	█	█	█	█								
#6 DC Motors	5	2	ALL	5	3	50%	█	█	█	█	█								
wheels	6	5	ALL	6	5	50%	█	█	█	█	█	█							
battery	6	1	ALL	5	2	50%	█	█	█	█	█	█							
Prepare midterm Presentation	7	3	ALL	7	3	70%	█	█	█	█	█	█							
chassis	8	2	ALL	8	2	80%	█	█	█	█	█	█							
Order DC Motors	9	3	ALL	9	3	70%	█	█	█	█	█	█							
Autonomous Mode	9	4	TBD	8	4	0%							█	█	█	█			
Line Following	10	2	TBD	10	2	0%													
Planning for Assembling	10	1	TBD	11	2	0%													
Assembling	11	2	TBD	12	2	0%													
Testing Autonomous Mode	12	2	TBD	12	2	0%													
Testing Line Following	12	2	TBD	12	3	0%													
Prepapre final report	12	3	ALL	12	3	0%													
Prepapre final presentation	13	2	ALL	13	2	0%													



**Prince Mohammad Bin Fahd University (PMU)**  
Department of Electrical Engineering

**Design Methodology & Project Management**  
Instructor: Dr. Samir El Nakla

**Fall 2019-20**

### **Project Plan**

**The Curiosity Rover  
(Smart Rover for Exploring)**

#### **Team:**

Omar Yahya 201502345  
Bandar Albalawi 201101356  
Saad Alnassar 201500439  
Salman Alsunaid 201602839

#### **Project Advisor(s)**

Mr. Ahmed Abul Hussein

Submitted to  
Dr. Samir El Nakla

in this progress report we are going to discuss the following:

first we started working on the chassis while looking for the best suitable materials to make it strong and light weight. In addition, we started looking and planning dc motors for the wheels.

In this file you will find other previous progress documents.



**Prince Mohammad Bin Fahd University (PMU)**  
Department of Electrical Engineering

**Microprocessors**

**Fall 2019-20**

**Progress report**

**The Curiosity Rover  
(Smart Rover for Exploring)**

**Team:**

Omar Yahya 201502345

Bandar Albalawi 201101356

Saad Alnassar 201500439

**Instructor**

Mr. Ahmed Abul Hussein

In the past few weeks we managed to get the needed components for the chassis and other parts to make the rover run autonomously. However, we still need to get the motor drives to make the rover run. In addition, we ordered it and we are still waiting for the delivery. On the bright side we are done with coding part as shown in the other file. We plan to finish everything before this coming Monday.

### Last Progress Report Assessment III

The Curiosity Rover							Assessment III		Spring 2019/2020										
Saad Alnassar 201500439							Project PLAN												
Bandar Albalawi 201101356							Instructor: Dr. Sadiq Alhawaidi												
Salman Alsunaid 201602839							Period Highlight: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15												
Omar Yahya 201502345							Actual (beyond plan) % Complete (beyond plan)												
Advisor Mr. Abul Hussain							Plan Actual												
ACTIVITY	PLAN START	PLAN DURATION	Assigned To	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE	Periods (Weeks 1-15)												
Write a plan	1	1	ALL	1	1	100%	█												
Time Management	1	1	ALL	1	1	100%	█												
Finish The Plan	1	1	ALL	1	1	100%	█												
Submitting Previous documents	1	1	..	1	1	100%	█												
Search and Acquire Components	1	1	All	1	3	90%	█												
Chasses			..			66%													
Solution for Motor Place	2	3	Salman	2	1	100%	█												
Legs	2	3	Salman	0	0	100%													
Bomber	7	3	Salman			0%													
Arm			..			50%													
Order	2	4	Bandar	2	2	100%	█												
Insallation	6	2	Saad & Bandar			0%													
Programming			..			60%													
IMU Sensors	2	1	Saad	3	1	80%	█												
Arduino	2	1	Saad	4	1	50%	█												
Control Mood	4	2	Omar	0	0	50%													
Autonomose Mood	4	2	Omar	0	0	50%													
Arm Program	4	2	Omar	5	1	70%	█												
Solar System			..			60%													
Solar Panel	2	4	Saad & Bandar	1		70%	█												
Tracking System	2	5	Saad & Bandar			50%													
Camera System			..			50%													
Order	3	2	Omar			100%													
Installation	4	3	Omar			0%													
Final Testing	8	2	ALL			0%													
Prepapre final presentation repor	12	3	ALL			90%													
Project demo w/ppt/rpt/banner	12	2	ALL			0%													

**Progress Details:**

- Working on The Final Report
- Added on the final report two sections
- Section #1 Future Work and Expected Final Prototype/Results.
- Section #2 Limitation and Challenges

**Issues (delay ...):**

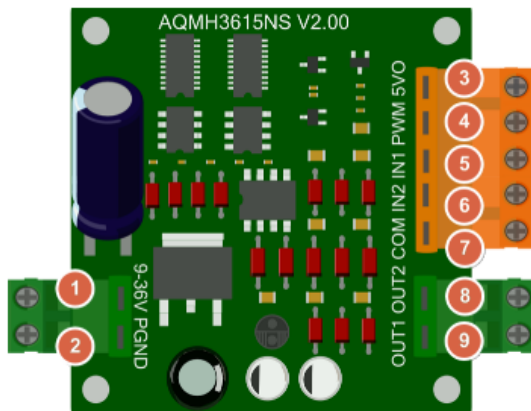
- Due to COVID-19 and the quarantine:
- 1-not able to go to PMU and collect the Rover
- 2-cannot test the codes
- 3- cannot meet together

## Appendix B: Bill of Materials

<b>Item</b>	<b>Quantity</b>	<b>Unit Cost (SR)</b>	<b>Subtotal</b>
Battery	1	150	150
Motor Drives	6	80	320
Chassis & Wheels	1	1000	1000
DC Motor	6	100	600
Solar Panel	2	150	300
Microcontroller	2	65	130
Servo Motor	2	100	200
Robotic Arm	1	800	800
			<b>Total= 3500 SR</b>

## Appendix C: Datasheets

Board Overview



Num	Label	Description
1	9 - 36V	Power Supply,
2	PGND	Power Supply, GND/ -
3	5V0	5V Output, you can use this power to feed Arduino through Arduino's 5V port, NOT Vin which requires 7-12V input
4	PWM	Speed control signal input
5	IN1	Motor steering control signal input 1, Note1
6	IN2	Motor steering control signal input 2
7	COM	GND
8	OUT2	Motor_
9	OUT1	Motor_-

Control Method

### Data Sheet of Motor Drive

Stalling this gear motor could cause gear damage.

\*At Nominal Voltage

Voltage (Nominal)	12V
Speed (No Load)*	105 RPM
Current (No Load)*	0.25A
Current (Stall)*	9.2A
Torque (Stall)*	720 oz-in
Gear Ratio	53.475:1
Gear Material	Metal
Gearbox Style	Spur
Motor Type	DC
Motor Brush Type	Brushed
Output Shaft Diameter	6mm
Output Shaft Style	d-shaft
Electrical Connection	Motor: 3.5mm Bullet Connectors , Encoder: 4-Pos JST XH
Wire Length	18.50in (470mm)
Product Weight	339g
Encoder: Cycles Per Revolution (Motor Shaft)	7 (Rises of Ch A)
Encoder: Cycles Per Revolution (Output Shaft)	374.325 (Rises of Ch A)
Encoder: Countable Events Per Revolution (Motor Shaft)	28 (Rises & Falls of Ch A & B)
Encoder: Countable Events Per Revolution (Output Shaft)	1,497.325 (Rises & Falls of Ch A & B)
Encoder Type	Relative, Quadrature
Encoder Sensor Type	Magnetic (Hall Effect)
Encoder Sensor Input Voltage Range	3.3 - 5VDC

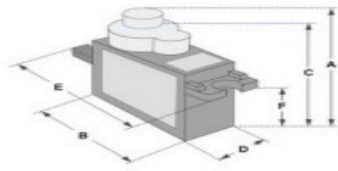
### Data Sheet of 12V DC Motor

## SERVO MOTOR SG90

## DATA SHEET

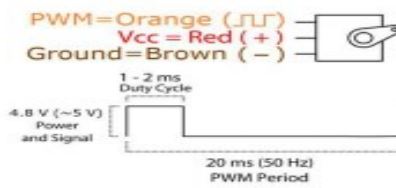


Tiny and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction), and works just like the standard kinds but smaller. You can use any servo code, hardware or library to control these servos. Good for beginners who want to make stuff move without building a motor controller with feedback & gear box, especially since it will fit in small places. It comes with a 3 horns (arms) and hardware.



Position "0" (1.5 ms pulse) is middle, "90" (-2ms pulse) is middle, is all the way to the right, "-90" (-1ms pulse) is all the way to the left.

Dimensions & Specifications	
A (mm) :	32
B (mm) :	23
C (mm) :	28.5
D (mm) :	12
E (mm) :	32
F (mm) :	19.5
Speed (sec) :	0.1
Torque (kg-cm) :	2.5
Weight (g) :	14.7
Voltage :	4.8 - 6



Data sheet of Servo Motor

## Appendix D: Program Codes

- Code for control mode using Bluetooth:

```
#define pwm_r1 3 // speed pin for the first right back wheels.
#define pwm_r2 4 // speed pin for the second right back wheels.
#define dir_l1 53 // direction for first left back motor
#define dir_l2 47 // direction for second left back motor
#define dir_r1 51 // direction for first right back motor
#define dir_r2 49 // direction for second right back motor
#define pwm_l1 2 // speed pin for the first left back wheels.
#define pwm_l2 5 // speed pin for the second left back wheels.
#define dir_fl 43 //direction for first left front motor
#define dir_fr 45 //direction for first right front motor
#define pwm_fl 7 // speed pin for the second left back wheels.
#define pwm_fr 6 // speed pin for the second left back wheels.

#define brk_l1 52 // breack
#define brk_l2 46
#define brk_r1 50
#define brk_r2 48
#define brk_fl 42
#define brk_fr 44
char detect=0;
int speeds=100;
```

```

void setup() {
  // put your setup code here, to run once:
  pinMode(trigPinf, OUTPUT);
  pinMode(echoPinf, INPUT);
  pinMode(dir_r1, OUTPUT);
  pinMode(dir_r2, OUTPUT);
  pinMode(dir_l1, OUTPUT);
  pinMode(dir_l2, OUTPUT);
  pinMode(dir_fl, OUTPUT);
  pinMode(dir_fr, OUTPUT);

  pinMode(pwm_l1, OUTPUT);
  pinMode(pwm_l2, OUTPUT);
  pinMode(pwm_r1, OUTPUT);
  pinMode(pwm_r2, OUTPUT);
  pinMode(pwm_fl, OUTPUT);
  pinMode(pwm_fr, OUTPUT);

  pinMode (brk_l1,OUTPUT);
  pinMode (brk_r1,OUTPUT);
  pinMode (brk_l2,OUTPUT);
  pinMode (brk_r2,OUTPUT);
  pinMode (brk_fl,OUTPUT);
  pinMode (brk_fr,OUTPUT);

  Serial.begin(9600);
  Serial1.begin(9600);

}

void distf() {
  digitalWrite(trigPinf, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPinf, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinf, LOW);

  durationf = pulseIn(echoPinf, HIGH);
  distanceCmf= durationf*0.034/2;
  Serial.println(distanceCmf);
}

void distf2() {
  digitalWrite(trigPinf2, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPinf2, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPinf2, LOW);

  durationf2 = pulseIn(echoPinf2, HIGH);
  distanceCmf2= durationf2*0.034/2;
  Serial.println(distanceCmf2);
}

void increase_speeds()
{
  if(speeds<200)
  speeds=speeds+20;

  analogWrite(pwm_r1, speeds);
  analogWrite(pwm_r2, speeds);
  analogWrite(pwm_l1, speeds);
  analogWrite(pwm_l2, speeds);
  analogWrite(pwm_fl, speeds);
  analogWrite(pwm_fr, speeds);
}

```

```

}

void decrease_speeds()
{
if(speeds>30)
speeds=speeds-30;

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);

}
void fronts()
{speeds=100;
Serial.println("FORWARD");
digitalWrite(dir_r1, LOW);
digitalWrite(dir_r2, LOW);
digitalWrite(dir_l1, LOW);
digitalWrite(dir_l2,LOW );
digitalWrite(dir_fl, LOW);
digitalWrite(dir_fr, LOW);

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);
}

void backs()
{

Serial.println("BACKS");

digitalWrite(dir_r1, HIGH);
digitalWrite(dir_r2, HIGH);
digitalWrite(dir_l1, HIGH);
digitalWrite(dir_l2,HIGH );
digitalWrite(dir_fl, HIGH);
digitalWrite(dir_fr, HIGH);

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);

}

void rights()
{

Serial.println("rights");

```

```

digitalWrite(dir_r1, LOW);
digitalWrite(dir_r2, LOW);
digitalWrite(dir_l1, HIGH);
digitalWrite(dir_l2,HIGH );
digitalWrite(dir_fl, HIGH);
digitalWrite(dir_fr, LOW);

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds-30);
analogWrite(pwm_l2, speeds-30);
analogWrite(pwm_fl, speeds-30);
analogWrite(pwm_fr, speeds);

}

void lefts()
{

Serial.println("lefts");

digitalWrite(dir_r1, HIGH);
digitalWrite(dir_r2, HIGH);
digitalWrite(dir_l1, LOW);
digitalWrite(dir_l2,LOW );
digitalWrite(dir_fl, LOW);
digitalWrite(dir_fr, HIGH);

analogWrite(pwm_r1, speeds-30);
analogWrite(pwm_r2, speeds-30);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds-30);

}

void stops()
{

Serial.println("stops");

digitalWrite(dir_r1, LOW);
digitalWrite(dir_r2, LOW);
digitalWrite(dir_l1, LOW);
digitalWrite(dir_l2,LOW );
digitalWrite(dir_fl, LOW);
digitalWrite(dir_fr, LOW);

analogWrite(pwm_r1, 0);
analogWrite(pwm_r2, 0);
analogWrite(pwm_l1, 0);
analogWrite(pwm_l2, 0);
analogWrite(pwm_fl, 0);
analogWrite(pwm_fr, 0);

}

void bluetooth()
{

```

```

detect=Serial1.read();
if(detect>49)
Serial.println(detect);

```

```

if(detect=='f')
{fronts();

}
if(detect=='i')
{increase_speeds();

}
if(detect=='d')
{decrease_speeds();

}
if(detect=='b')
{backs();

}

if(detect=='l')
{lefts();

}

if(detect=='r')
{rights();

}

if(detect=='s')
{stops();

}

```

```

delay(100);

```

```

}

```

```

void loop() {
//bluetooth();// this loop is used for bluetooth control
//distf2();
distf();

```

```

}

```

Code for obstacle avoiding using ultrasonic:

```

#include<Servo.h>
#include <NewPing.h>
Servo myservo1;
#define SONAR_NUM 3 // Number of sensors.
#define MAX_DISTANCE 100 // Maximum distance (in cm) to ping.

```

```

#define pwm_r1 5 // speed pin for the first right back wheels.
#define pwm_r2 4 // speed pin for the second right back wheels.
#define dir_l1 53 // direction for first left back motor
#define dir_l2 51 // direction for second left back motor
#define dir_r1 47 // direction for first right back motor
#define dir_r2 49 // direction for second right back motor
#define pwm_l1 2 // speed pin for the first left back wheels.
#define pwm_l2 3 // speed pin for the second left back wheels.
#define dir_fl 43 //direction for first left front motor
#define dir_fr 45 //direction for first right front motor
#define pwm_fl 7 // speed pin for the second left back wheels.
#define pwm_fr 6 // speed pin for the second left back wheels.

int switcher=24;
#define brk_l1 52 // breack
#define brk_l2 50
#define brk_r1 46
#define brk_r2 48
#define brk_fl 42
#define brk_fr 44
char detect=0;
int speeds=40;

int front_top=0;
int front_bottom=0;
int back=0;
NewPing sonar[SONAR_NUM] = { // Sensor object array.
  NewPing(40, 41, MAX_DISTANCE), // Each sensor's trigger pin, echo pin, and max distance to ping.
  NewPing(34,35 , MAX_DISTANCE),
  NewPing(26, 28, MAX_DISTANCE)
};

void setup() {
  Serial.begin(9600); // Open serial monitor at 115200 baud to see ping results.
  myservo1.attach(33);
  pinMode(dir_r1, OUTPUT);
  pinMode(dir_r2, OUTPUT);
  pinMode(dir_l1, OUTPUT);
  pinMode(dir_l2, OUTPUT);
  pinMode(dir_fl, OUTPUT);
  pinMode(dir_fr, OUTPUT);

  pinMode(pwm_l1, OUTPUT);
  pinMode(pwm_l2, OUTPUT);
  pinMode(pwm_r1, OUTPUT);
  pinMode(pwm_r2, OUTPUT);
  pinMode(pwm_fl, OUTPUT);
  pinMode(pwm_fr, OUTPUT);

  pinMode(brk_l1,OUTPUT);
  pinMode(brk_r1,OUTPUT);
  pinMode(brk_l2,OUTPUT);
  pinMode(brk_r2,OUTPUT);
  pinMode(brk_fl,OUTPUT);
  pinMode(brk_fr,OUTPUT);
  pinMode(switcher,INPUT);
  Serial.begin(9600);
  Serial1.begin(9600);
}

void calc_dist() {
  for (uint8_t i = 0; i < SONAR_NUM; i++) { // Loop through each sensor and display results.
    delay(50); // Wait 50ms between pings (about 20 pings/sec). 29ms should be the shortest delay between pings.
    Serial.print(i);
    Serial.print("=");
  }
}

```

```

Serial.print(sonar[i].ping_cm());
Serial.print("cm ");

}
front_top=sonar[1].ping_cm();
front_bottom=sonar[2].ping_cm();
back= sonar[0].ping_cm();
Serial.println();
}

```

```

void increase_speeds()
{
if(speeds<200)
speeds=speeds+20;

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);

}

```

```

void decrease_speeds()
{
if(speeds>30)
speeds=speeds-30;

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);

}

```

```

}
void fronts()
{speeds=100;
Serial.println("FORWARD");
digitalWrite(dir_r1, LOW);
digitalWrite(dir_r2, LOW);
digitalWrite(dir_l1, LOW);
digitalWrite(dir_l2,LOW );
digitalWrite(dir_fl, LOW);
digitalWrite(dir_fr, LOW);
}

```

```

analogWrite(pwm_r1, speeds);
analogWrite(pwm_r2, speeds);
analogWrite(pwm_l1, speeds);
analogWrite(pwm_l2, speeds);
analogWrite(pwm_fl, speeds);
analogWrite(pwm_fr, speeds);
}

```

```

void backs()
{

    Serial.println("BACKS");

    digitalWrite(dir_r1, HIGH);
    digitalWrite(dir_r2, HIGH);
    digitalWrite(dir_l1, HIGH);
    digitalWrite(dir_l2,HIGH );
    digitalWrite(dir_fl, HIGH);
    digitalWrite(dir_fr, HIGH);

    analogWrite(pwm_r1, speeds);
    analogWrite(pwm_r2, speeds);
    analogWrite(pwm_l1, speeds);
    analogWrite(pwm_l2, speeds);
    analogWrite(pwm_fl, speeds);
    analogWrite(pwm_fr, speeds);

}

void rights()
{

    Serial.println("rights");

    digitalWrite(dir_r1, LOW);
    digitalWrite(dir_r2, LOW);
    digitalWrite(dir_l1, HIGH);
    digitalWrite(dir_l2,HIGH );
    digitalWrite(dir_fl, HIGH);
    digitalWrite(dir_fr, LOW);

    analogWrite(pwm_r1, speeds);
    analogWrite(pwm_r2, speeds);
    analogWrite(pwm_l1, speeds-30);
    analogWrite(pwm_l2, speeds-30);
    analogWrite(pwm_fl, speeds-30);
    analogWrite(pwm_fr, speeds);

}

void lefts()
{

    Serial.println("lefts");

    digitalWrite(dir_r1, HIGH);
    digitalWrite(dir_r2, HIGH);
    digitalWrite(dir_l1, LOW);
    digitalWrite(dir_l2,LOW );
    digitalWrite(dir_fl, LOW);
    digitalWrite(dir_fr, HIGH);

    analogWrite(pwm_r1, speeds-30);
    analogWrite(pwm_r2, speeds-30);
    analogWrite(pwm_l1, speeds);
    analogWrite(pwm_l2, speeds);
    analogWrite(pwm_fl, speeds);
    analogWrite(pwm_fr, speeds-30);

}

```

```

void stops()
{
    Serial.println("stops");

    digitalWrite(dir_r1, LOW);
    digitalWrite(dir_r2, LOW);
    digitalWrite(dir_l1, LOW);
    digitalWrite(dir_l2, LOW);
    digitalWrite(dir_fl, LOW);
    digitalWrite(dir_fr, LOW);

    analogWrite(pwm_r1, 0);
    analogWrite(pwm_r2, 0);
    analogWrite(pwm_l1, 0);
    analogWrite(pwm_l2, 0);
    analogWrite(pwm_fl, 0);
    analogWrite(pwm_fr, 0);

}

void bluetooth()
{
    detect=Serial1.read();
    if(detect>49)
    Serial.println(detect);

    if(detect=='f')
    {fronts();

    }
    if(detect=='i')
    {increase_speeds();

    }
    if(detect=='d')
    {decrease_speeds();

    }
    if(detect=='b')
    {backs();

    }

    if(detect=='l')
    {lefts();

    }

    if(detect=='r')
    {rights();

    }

    if(detect=='s')
    {stops();

    }
}

```

```

delay(100);

}

void auto_mode()
{

  calc_dist();
  myservo1.write(90);

  if(front_top<30 && front_top!=0)
  {
  stops();

  int d_left=0;
  int d_right=0;
  myservo1.write(180);
  delay(2000);
  calc_dist();
  d_right=front_top;

  myservo1.write(150);
  delay(300);
  myservo1.write(130);
  delay(300);
  myservo1.write(110);
  delay(300);
  myservo1.write(90);
  delay(300);
  myservo1.write(70);
  delay(300);
  myservo1.write(50);
  delay(300);
  myservo1.write(30);
  delay(300);
  myservo1.write(10);
  delay(300);

  myservo1.write(0);
  delay(2000);
  calc_dist();
  d_left=front_top;

  if(d_left==0)
  {lefts();
  delay(1000);
  stops();
  delay(1000);
  }
  else
  if(d_right==0)
  {rights();
  delay(1000);
  stops();
  delay(1000);}
  else if ((d_right-d_left)>0)
  {lefts();
  delay(1000);

```

```

stops();
delay(1000);}

else if((d_left-d_right)>0)
{rights();
delay(1000);
stops();
delay(1000);}

else
{backs();
delay(1000);
stops();
delay(1000);
}

}

```

```

if(front_bottom<30 && front_bottom!=0)
{

stops();

int d_left=0;
int d_right=0;
myservo1.write(180);
delay(2000);
calc_dist();
d_right=front_top;

myservo1.write(150);
delay(300);
myservo1.write(130);
delay(300);
myservo1.write(110);
delay(300);
myservo1.write(90);
delay(300);
myservo1.write(70);
delay(300);
myservo1.write(50);
delay(300);
myservo1.write(30);
delay(300);
myservo1.write(10);
delay(300);

myservo1.write(0);
delay(2000);
calc_dist();
d_left=front_top;

```

```

if(d_left==0)
{lefts();
delay(1000);
stops();
delay(1000);
}
else
if(d_right==0)
{rights();
delay(1000);
stops();
delay(1000);}
else if ((d_right-d_left)>0)
{lefts();
delay(1000);
stops();
delay(1000);}

else if((d_left-d_right)>0)
{rights();
delay(1000);
stops();
delay(1000);}

else
{backs();
delay(1000);
stops();
delay(1000);
}
}

else

if(back<30 && back!=0)
{Serial.println("back obstacle");

stops();

}
else
{fronts();}

}

void loop()
{
if(digitalRead(switche)==1)
auto_mode();
Serial.println(digitalRead(switche));

if(digitalRead(switche)==0)
bluetooth();

}

```

## Appendix E: Operation Manual

### ➤ Run project prototype:

First, to start run the rover we need to connect the battery to the rover to connect the power. Then if we want to use the Bluetooth first we make sure that the Bluetooth is connecting then download the code into the Arduino then we can test by using an app of control mode by Bluetooth. Moreover, we will use the same procedure for the ultrasonic sensor for autonomous mode.

### ➤ List expected outputs

In our project the expected output is to move in two ways by control mode or autonomous mode these are the important specification of our project. Also, we expected to use a solar panel for charging our battery to provide 2 A by connecting two parallel panels. Furthermore, we used the transmitter and receiver to send a signal from the joy stick to the receiver that its connected to Arduino board